Study and Review of Biogas Experience in Bangladesh and other Countries

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I confirm that this thesis represents my own work; the contribution of any supervisors and others to the research and to the thesis was consistent with normal supervisor practice. External contributions to the research are acknowledged.

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Supervisor's Declaration

The MS level research on **"Study and Review of Biogas Experience in Bangladesh and other Countries"** has been carried out and the dissertation was prepared under my direct supervision. Here I confirm that, to the best of my knowledge the thesis represents the original research work of the candidate; the contribution made to the research the by me, by others of the university was consistent with normal supervisory practice and external contributions to the research are acknowledged.

I believe the thesis to be in a suitable presentational from and is ready for examination.

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Abstract

With large amount of population (density $1113.98/km^2$) Bangladesh demand a large amount of energy. But its economic condition is not enough strong to yield and endure with demand of energy for increasing population and raising economy. Alternative source of energy especially biogas technology has been initiated in Bangladesh for many years. Bangladesh is blessed with congruous geographical location (20^0 $34^/$ N – 26^0 $38^/$ N, 88^0 $01^/$ – 92^0 $41^/$ E) for renewable energy and perfect weather condition for Biomass energy. It is a low lying and tropical country and its temperature is very suitable for the fermentation of organic materials throughout the year. But in this country biogas technology is not popular as it was presumed. This study is conducted with the desire to investigate the reasons why biogas technology is not yet popular as like as solar home system (SHS) in both grid and off grid areas in Bangladesh. The expense of per unit PV electricity is ultimately higher than biogas scheme. Poor people can't bear the expenditure for such technology but it is often seen that they have a solar panel on their roof. Bangladesh is eager to invest huge amount of money in fossil fuel based electricity plant and buy electricity from neighbour countries also. This study does not trying to discover the lacking of other renewable energy sources rather an attempt to investigate the experience of biogas technology in Bangladesh. Gradually Bangladeshi people is adopting renewable energy, it is now required to accelerate this adoption to complement the requisite amount of energy for extended population and blooming economy .This review work focuses on the drawback of biogas technology on the basis of opinion and speculation of who use and who does not use biogas. In addition, people will get benefits from improved plant growth and crop yields through bio-slurry use. The financial benefits are likely greater when switching from liquid petroleum gas (LPG) to biogas as opposed to changing from collected wood to biogas. In this way it will be possible to make a hit to economy and environment.

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Nomenclature

BBS	Bangladesh Bureau of Statistics
BERC	Bangladesh Energy Regulatory Commission
BP	Bangladesh Plan
BPDB	Bangladesh Power Development Board
BPRE	Bangladesh Policy of Renewable Energy
BRAC	Bangladesh Rural Advancement Committee
IE	Institute of Energy, DU
CDM	Clean Development Mechanism
DC	Direct Current
GDP	Gross Domestic Product
GOB	Government of the People's Republic of Bangladesh
ICT	Information and Communication Technology
LGED	Local Government Engineering Department
MOF	Ministry of Finance
MDG	Millennium Development Goals
MPEMR	Ministry of Power, Energy and Mineral Resources
NEP	National Energy Policy
NGOs	Non-Government Organizations
PV	Photovoltaic
RE	Renewable Energy
REB	Rural Electrification Board
R&D	Research and Development
RETs	Renewable Energy Technologies
RSF	Research Support Facility
SRE	Sustainable Rural Energy
SREF	Small Renewable Energy Program
SHSs	Solar Home Systems
SREDA	Sustainable and Renewable Energy Development Agency
SNV	Netherlands Development Organization
DANIDA	Danish International Development Agency
BDT	Bangladesh Taka
USD	United States Dollar
WB	World Bank
NDBMP	National Domestic Biogas & Manure Programme
GOB	Government of Bangladesh
MoYS	Ministry of Youth and Sports
GTZ	German Technical Cooperation
HH	Household
IDCOL	Infrastructure Development Company Ltd
IFRD	Institute of Fuel Research and Development
LGED	Local Government Engineering Department

Subscript

Ktons	kilotons
sq. km	square kilometer
%	percentage
M/s	meter per second
1C	degrees Celsius

1F	degrees Fahrenheit
Cft	Cubic feet
MJ/m^2	mega joule per meter square
GWh	giga watt hour
KWh/m^2	kilowatt hour per meter square
kWp	kilowatt peak
MWp	megawatt peak
KW	kilowatt
MW	megawatt
KWh/m2/yr	kilowatt hour per meter square per year
W/m^2	watt per meter square

Chapter One

Introduction

1.1 Background of study

Demands of energy are increasing globally at every instant. Due to the depleted source of fossil fuels as well as changing the prices of fossil fuels sometimes shape global politics on the basis of the availability of energy source. Healthy and low expense renewable energy sources can be replaced fossil fuels. Meanwhile, renewable energy plays a vital role to cope with the increasing demands of energy in developed countries. They use not only the fundamental technologies of renewable energy such as geothermal energy, wind energy, nuclear energy, tidal power, wave energy, hydro power, solar energy, biogas etc. but also hydrogen fuel cell, bio methane etc. technologies. Similarly, developing countries can also accomplish the demands of energy by using renewable energy following the developed countries. Today large amount of people in Bangladesh faces a gigantic crisis of energy due to the reduction of its exploration base energy such as gas, coal, oil etc. and slow blooming economy. The government of Bangladesh has taken many swift and effective steps to produce energy which are mainly planned to supply energy to the grid area by using fossil fuel. In Bangladesh, only 3% of the population enjoys the facility of natural gas coming to their homes through pipelines. The lucky few mostly live in the city areas. Majority of the remaining 97% still depend on biomass fuels for cooking and more than 50 million tons of biomass fuels are being used every year in this regard. At every turn, it is experienced that people living in the rural area does not get grid energy facilities and the people live in town area sometimes face huge crisis of power specially gas and electricity. City Corporation and WASA spend a huge amount of efforts as well as money, energy to maintain the recycle process of waste every year in the big cities like Dhaka, Chittagong etc. without getting back any energy or profit. Similarly, rural people use biomass sources such as cow dung; wood etc. by processing in traditional way which is unsustainable. Traditionally, they use these biomass sources only for cooking which is not only unsustainable but also troublesome task. It has harmful impacts directly to the environment and indirectly on our economy. Biogas technology can be used to implement a sustainable energy and waste management program, which can provide the necessary energy requirements for cooking and lighting. Apart from the energy, the treated slurry produced as a bi-product from biogas digesters is a very good organic fertilizer. It is the best way to recycle the waste and get back energy with low cost is justified by many researchers and organizations. The blasting side of traditional fossil fuel has been known by all. Yet there are no perceptible steps have been taken to switch from traditional fossil fuel to biogas or other renewable energy such as solar energy, hydropower, nuclear energy, tidal power, wave energy, wind etc. Due to congruous geographical location and perfect weather condition of Bangladesh, biogas scheme is the lowest expensive and easy operate able energy source. The producing expense of per unit electricity from other renewable energy is higher than biogas scheme. Poor people cannot pay enough money for PV technology but it is often experienced that they have a solar panel on their roof. In the town area solar panel on the roof instead of adopting portable biogas is a common experience. In addition, in case of gas crisis people spontaneously pay about TK1200-1700 per LPG cylinder with its own disadvantage and risk. Although biogas is environment friendly, risk free with low producing cost they are not interested to adopt portable or general biogas scheme.

1.2 Various renewable energy sources

In general a kind of energy is called Renewable if its source cannot run out (like the sun) or can easily be replaced (like wood, as we can plant trees to use for energy) and their sources are carbon neutral. This means they do not produce Carbon compounds (such as other greenhouse gases). These also do not pollute the environment (air, land or water). Renewable energy is energy which can be obtained from natural resources that can be constantly replenished. Renewable energy technologies include technologies that use—or enable the use of—one or more renewable energy sources [1] Renewable energy often provides energy in four important areas: electricity generation, air and water heating/cooling, transportation, and rural (off-grid) energy services. [2]

Based on REN21's 2016 report, renewables contributed 19.2% to humans' global energy consumption and 23.7% to their generation of electricity in 2014 and 2015, respectively. This energy consumption is divided as 8.9% coming from traditional biomass, 4.2% as heat energy (modern biomass, geothermal and solar heat), 3.9% hydroelectricity and 2.2% is electricity from wind, solar, geothermal, and biomass. Worldwide investments in renewable technologies amounted to more than US$286 billion in 2015, with countries like China and the United States heavily investing in wind, hydro, solar and biofuels.[3] Globally, there are an estimated 7.7 million jobs associated with the renewable energy industries, with solar photovoltaic being the largest renewable employer.[4]

Renewable energy resources exist over wide geographical areas, in contrast to other energy sources, which are concentrated in a limited number of countries. Rapid deployment of renewable energy and energy efficiency is resulting in significant energy security, climate change mitigation, and economic benefits. [5] The results of a recent review of the literature [6] concluded that as greenhouse gas (GHG) emitters begin to be held liable for damages resulting from GHG emissions resulting in climate change, a high value for liability mitigation would provide powerful incentives for deployment of renewable energy technologies. In international public opinion surveys there is strong support for promoting renewable sources such as solar power and wind power. [7] At the national level, at least 30 nations around the world already have renewable energy contributing more than 20 percent of energy supply. National renewable energy markets are projected to continue to grow strongly in the coming decade and beyond.[8] Some places and at least two countries, Iceland and Norway generate all their electricity using renewable energy already, and many other countries have the set a goal to reach 100%

renewable energy in the future. For example, in Denmark the government decided to switch the total energy supply (electricity, mobility and heating/cooling) to 100% renewable energy by 2050. [9]

While many renewable energy projects are large-scale, renewable technologies are also suited to rural and remote areas and developing countries, where energy is often crucial in human development.[10] United Nations' Secretary-General Ban Ki-moon has said that renewable energy has the ability to lift the poorest nations to new levels of prosperity.[11] As most of renewables provide electricity, renewable energy deployment is often applied in conjunction with further electrification, which has several benefits: For example, electricity can be converted to heat without losses and even reach higher temperatures than fossil fuels, can be converted into mechanical energy with high efficiency and is clean at the point of consumption.[12][13] In addition to that electrification with renewable energy is much more efficient and therefore leads to a significant reduction in primary energy requirements, because most renewables don't have a steam cycle with high losses (fossil power plants usually have losses of 40 to 65%).[14]

1.2.1 Solar Energy

Solar energy is radiant light and heat from the Sun that is harnessed using a range of ever-evolving technologies such as solar heating, photovoltaic, solar thermal energy, solar architecture and artificial photosynthesis. [15][16]

It is an important source of renewable energy and its technologies are broadly characterized as either passive solar or active solar depending on how they capture and distribute solar energy or convert it into solar power. Active solar techniques include the use of photovoltaic systems, concentrated solar power and solar water heating to harness the energy. Passive solar techniques include orienting a building to the Sun, selecting materials with favorable thermal mass or light-dispersing properties, and designing spaces that naturally circulate air.

The large magnitude of solar energy available makes it a highly appealing source of electricity. The United Nations Development Programming its 2000 World Energy Assessment found that the annual potential of solar energy was 1,575–49,837 exajoules (EJ). This is several times larger than the total world energy consumption, which was 559.8 EJ in 2012. [17][18]

In 2011, the International Energy Agency said that "the development of affordable, inexhaustible and clean solar energy technologies will have huge longer-term benefits. It will increase countries' energy security through reliance on an indigenous, inexhaustible and mostly import-independent resource, enhance sustainability, reduce pollution, lower the costs of mitigating global warming, and keep fossil fuel prices lower than otherwise. These advantages are global. Hence the additional costs of the incentives for early deployment should be considered learning investments; they must be wisely spent and need to be widely shared". [15]

Solar thermal energy (STE)

Solar thermal energy (STE) is a form of energy and a technology for harnessing solar energy to generate thermal energy or electrical energy for use in industry, and in the residential and commercial sectors. Solar thermal technologies can be used for water heating, space heating and space cooling and process heat generation. [19]

Photovoltaic (PV)

Photovoltaic (PV) covers the conversion of light into electricity using semiconducting materials that exhibit the photovoltaic effect, a phenomenon studied in physics, photochemistry, and electrochemistry.

A typical photovoltaic system employs solar panels, each comprising a number of solar cells, which generate electrical power. The first step is the photoelectric effect followed by an electrochemical process where crystallized atoms, ionized in a series, generate an electric current. [20] PV Installations may be ground-mounted, rooftop mounted or wall mounted.

Solar PV generates no pollution. [21] The direct conversion of sunlight to electricity occurs without any moving parts. Photovoltaic systems have been used for fifty years in specialized applications, standalone and grid-connected PV systems have been in use for more than twenty years. [22] They were first mass-produced in 2000, when German environmentalists and the Euro solar organization got government funding for a ten thousand roof program. [23]

On the other hand, grid-connected PV systems have the major disadvantage that the power output is dependent on direct sunlight, so by definition, solar power systems only produce power for half of a day and less if tracking is not used. Power output is also adversely affected by weather conditions, especially cloud cover. This means that, in the national grid for example, this power has to be made up by other power sources: hydrocarbon, nuclear, hydroelectric or wind energy. To some, solar installations also have a negative aesthetic impact on an area. Advances in technology and increased manufacturing scale have reduced the cost, increased the reliability, and increased the efficiency of photovoltaic installations[22][24] and the liveliest cost of electricity from PV is competitive, on a kilowatt/ hour basis, with conventional electricity sources in an expanding list of geographic regions.[25] Solar PV regularly costs USD 0.05-0.10 per kilowatt-hour (kWh) in Europe, China, India, South Africa and the United States.[26] In 2015, record low prices were set in the United Arab Emirates (5.84 cents/kWh), Peru (4.8 cents/kWh) and Mexico (4.8 cents/kWh). In May 2016, a solar PV auction in Dubai attracted a bid of 3 cents/kWh. [27]

Net metering and financial incentives, such as preferential feed-in tariffs for solar-generated electricity; have supported solar PV installations in many countries. [28] More than 100 countries now use solar PV. After hydro and wind power, PV is the third renewable energy source in terms of globally capacity. In 2014, worldwide installed PV capacity increased to 177 giga watts (GW), which is two percent of global electricity demand.[29] China, followed by Japan and the United States, is the fastest growing market, while Germany remains the world's largest producer (both in per capita and absolute terms), with solar PV providing seven percent of annual domestic electricity consumption.[30]

1.2.2 Geothermal energy

Geothermal energy is thermal energy generated and stored in the Earth. Thermal energy is the energy that determines the temperature of matter. The geothermal energy of the Earth's crust originates from the original formation of the planet and from radioactive decay of materials (in currently uncertain [31] but possibly roughly equal [32] proportions). The geothermal gradient, which is the difference in temperature between the core of the planet and its surface, drives a continuous conduction of thermal energy in the form of heat from the core to the surface.

Earth's internal heat is thermal energy generated from radioactive decay and continual heat loss from Earth's formation. [33] Temperatures at the core–mantle boundary may reach over 4000 °C (7,200 °F).[34] The high temperature and pressure in Earth's interior cause some rock to melt and solid mantle to behave plastically, resulting in portions of mantle convecting upward since it is lighter than the surrounding rock. Rock and water is heated in the crust, sometimes up to 370 °C (700 °F). [35]

From hot springs, geothermal energy has been used for bathing since Paleolithic times and for space heating since ancient Roman times, but it is now better known for electricity generation. Worldwide, 11,700 megawatts(MW) of geothermal power is online in 2013.[36] An additional 28 gigawatts of direct geothermal heating capacity is installed for district heating, space heating, spas, industrial processes, desalination and agricultural applications in 2010.[37]

Geothermal power is cost-effective, reliable, sustainable, and environmentally friendly, [38] but has historically been limited to areas near tectonic plate boundaries. Recent technological advances have dramatically expanded the range and size of viable resources, especially for applications such as home heating, opening a potential for widespread exploitation. Geothermal wells release greenhouse gases trapped deep within the earth, but these emissions are much lower per energy unit than those of fossil fuels. As a result, geothermal power has the potential to help mitigate global warming if widely deployed in place of fossil fuels.

The Earth's geothermal resources are theoretically more than adequate to supply humanity's energy needs, but only a very small fraction may be profitably exploited. Drilling and exploration for deep resources is very expensive. Forecasts for the future of geothermal power depend on assumptions about technology, energy prices, subsidies, and interest rates. Pilot programs like EWEB's customer opt in Green Power Program [39] show that customers would be willing to pay a little more for a renewable energy source like geothermal. But as a result of government assisted research and industry experience, the cost of generating geothermal power has decreased by 25% over the past two decades.[40] In 2001, geothermal energy costs between two and ten US cents per kWh.[41]

Geothermal energy comes in either vapor-dominated or liquid-dominated forms. Larderello and The Geysers are vapor-dominated. Vapor-dominated sites offer temperatures from 240 to 300 °C that produce superheated steam.

1.2.3 Wind power

Wind power is the use of air flow through wind turbines to mechanically power generators for electricity. Wind power, as an alternative to burning fossil fuels, is plentiful, renewable, widely distributed, clean, produces no greenhouse gas emissions during operation, uses no water, and uses little land.[42] The net effects on the environment are far less problematic than those of nonrenewable power sources.

Wind farms consist of many individual wind turbines which are connected to the electric power transmission network. Onshore wind is an inexpensive source of electricity, competitive with or in many places cheaper than coal or gas plants.[43][44][45] Offshore wind is steadier and stronger than on land, and offshore farms have less visual impact, but construction and maintenance costs are considerably higher. Small onshore wind farms can feed some energy into the grid or provide electricity to isolated off-grid locations. [46]

Wind power gives variable power which is very consistent from year to year but which has significant variation over shorter time scales. It is therefore used in conjunction with other electric power sources to give a reliable supply. As the proportion of wind power in a region increases, a need to upgrade the grid, and a lowered ability to supplant conventional production can occur.[47][48] Power management techniques such as having excess capacity, geographically distributed turbines, dispatch able backing sources, sufficient hydroelectric power, exporting and importing power to neighboring areas, using vehicle-to-grid strategies or reducing demand when wind production is low, can in many cases overcome these problems.[49][50] In addition, weather forecasting permits the electricity network to be readied for the predictable variations in production that occur.[51][52]53]

As of 2015, Denmark generates 40% of its electricity from wind, [54] [55] and at least 83 other countries around the world are using wind power to supply their electricity grids. [56] In 2014 global wind power capacity expanded 16% to 369,553 MW.[57] Yearly wind energy production is also growing rapidly and has reached around 4% of worldwide electricity usage,[58] 11.4% in the EU.[59]

1.2.4 Wave power

Wave power is the transport of energy by wind waves, and the capture of that energy to do useful work – for example, electricity generation, water desalination, or the pumping of water (into reservoirs). A machine able to exploit wave power is generally known as a wave energy converter (WEC).

Wave power is distinct from the diurnal flux of tidal power and the steady gyre of ocean currents. Wave-power generation is not currently a widely employed commercial technology, although there have been attempts to use it since at least 1890. [60] In 2008, the first experimental wave farm was opened in Portugal, at the Aguçadoura Wave Park. [61]

Waves are generated by wind passing over the surface of the sea. As long as the waves propagate slower than the wind speed just above the waves, there is an energy transfer from the wind to the waves. Both air pressure differences between the upwind and the lee side of a wave crest, as well as friction on the water surface by the wind, making the water to go into the shear stress causes the growth of the waves. [63]

Wave height is determined by wind speed, the duration of time the wind has been blowing, fetch (the distance over which the wind excites the waves) and by the depth and topography of the seafloor (which can focus or disperse the energy of the waves). A given wind speed has a matching practical limit over which time or distance will not produce larger waves. When this limit has been reached the sea is said to be "fully developed".

In general, larger waves are more powerful but wave power is also determined by wave speed, wavelength, and water density.

Oscillatory motion is highest at the surface and diminishes exponentially with depth. However, for standing waves (clapotis) near a reflecting coast, wave energy is also present as pressure oscillations at great depth, producing microseisms. [63] These pressure fluctuations at greater depth are too small to be interesting from the point of view of wave power.

The waves propagate on the ocean surface, and the wave energy is also transported horizontally with the group velocity. The mean transport rate of the wave energy through a vertical plane of unit width, parallel to a wave crest, is called the wave energy flux (or wave power, which must not be confused with the actual power generated by a wave power device).

1.2.5 Hydropower or water power

Hydropower or water power is power derived from the energy of falling water or fast running water, which may be harnessed for useful purposes. Since ancient times, hydropower from many kinds of watermills has been used as a renewable energy source for irrigation and the operation of various mechanical devices, such as gristmills, sawmills textile mills, trip hammers, dock cranes, domestic lifts, and ore mills. A trompe, which produces compressed air from falling water, is sometimes used to power other machinery at a distance.

In the late 19th century, hydropower became a source for generating electricity. Crag side in Northumberland was the first house powered by hydroelectricity in 1878[64] and the first commercial hydroelectric power plant was built at Niagara Falls in 1879. In 1881, street lamps in the city of Niagara Falls were powered by hydropower.

Since the early 20th century, the term has been used almost exclusively in conjunction with the modern development of hydroelectric power. International institutions such as the World Bank view hydropower as a means for economic development without adding substantial amounts of carbon to the atmosphere, [65] but dam scan have significant negative social and environmental impacts. [66]

Hydraulic power-pipe networks

Hydraulic power networks used pipes to carrying pressurized water and transmit mechanical power from the source to end users. The power source was normally a head of water, which could also be assisted by a pump. These were extensive in Victorian cities in the United Kingdom. A hydraulic power network was also developed in Geneva, Switzerland. The world-famous Jet d'Eau was originally designed as the over-pressure relief valve for the network. [67]

Compressed air hydro

Where there is a plentiful head of water it can be made to generate compressed air directly without moving parts. In these designs, a falling column of water is purposely mixed with air bubbles generated through turbulence or a venture pressure reducer at the high level intake. This is allowed to fall down a shaft into a subterranean, high-roofed chamber where the now-compressed air separates from the water and becomes trapped. The height of the falling water column maintains compression of the air in the top of the chamber, while an outlet, submerged below the water level in the chamber allows water to flow back to the surface at a lower level than the intake. A separate outlet in the roof of the chamber supplies the compressed air. A facility on this principle was built on the Montreal River at Ragged Shutes near Cobalt, Ontario in 1910 and supplied 5,000 horsepower to nearby mines. [68]

Hydropower types

Hydropower is used primarily to generate electricity.

Broad categories include: Conventional hydroelectric, referring to hydroelectric dams. Run-of-the-river hydroelectricity, which captures the kinetic energy in rivers or streams, without a large reservoir and sometimes without the use of dams. Small hydro projects are 10 megawatts or less and often have no artificial reservoirs. Micro hydro projects provide a few kilowatts to a few hundred kilowatts to isolated homes, villages, or small industries. Conduit hydroelectricity projects utilize water which has already been diverted for use elsewhere; in a municipal water system, for example.

Pumped-storage hydroelectricity stores water pumped uphill into reservoirs during periods of low demand to be released for generation when demand is high or system generation is low.

1.2.6 Tidal power

Tidal power, also called tidal energy, is a form of hydropower that converts the energy obtained from tides into useful forms of power, mainly electricity.

Although not yet widely used, tidal power has potential for future electricity generation. Tides are more predictable than wind energy and solar power. Among sources of renewable energy, tidal power has traditionally suffered from relatively high cost and limited availability of sites with sufficiently high tidal ranges or flow velocities, thus constricting its total availability. However, many recent technological developments and improvements, both in design (e.g. dynamic tidal power, tidal lagoons) and turbine technology (e.g. new axial turbines, cross flow turbines), indicate that the total availability of tidal power may be much higher than previously assumed, and that economic and environmental costs may be brought down to competitive levels.

Historically, tide mills have been used both in Europe and on the Atlantic coast of North America. The incoming water was contained in large storage ponds, and as the tide went out, it turned waterwheels that used the mechanical power it produced to mill grain. [69] The earliest occurrences date from the Middle Ages, or even from Roman times.[70][71] It was only in the 19th century that the process of using falling water and spinning turbines to create electricity was introduced in the U.S. and Europe.[72]

The world's first large-scale tidal power plant is the Rance Tidal Power Station in France, which became operational in 1966. It was the largest tidal power station in terms of power output, before Sihwa Lake Tidal Power Station surpassed it. Total harvestable energy from tidal areas close to the coast is estimated to be around 1 terawatt worldwide. [73]

1.2.7 Biofuel

A biofuel is a fuel that is produced through contemporary biological processes, such as agriculture and anaerobic digestion, rather than a fuel produced by geological processes such as those involved in the formation of fossil fuels, such as coal and petroleum, from prehistoric biological matter. Biofuels can be derived directly from plants, or indirectly from agricultural, commercial, domestic, and/or industrial wastes. [74] Renewable biofuels generally involve contemporary carbon fixation, such as those that occur in plants or microalgae through the process of photosynthesis. Other renewable biofuels are made through the use or conversion of biomass (referring to recently living organisms, most often referring to plants or plant-derived materials). This biomass can be converted to convenient energy-containing substances in three different ways: thermal conversion, chemical conversion, and biochemical conversion. This biomass conversion can result in fuel in solid, liquid, or gas form. This new biomass can also be used directly for biofuels.

Bioethanol is an alcohol made by fermentation, mostly from carbohydrates produced in sugar or starch crops such as corn, sugarcane, or sweet sorghum. Cellulosic biomass, derived from non-food sources, such as trees and grasses, is also being developed as a feedstock for ethanol production. Ethanol can be used as a fuel for vehicles in its pure form, but it is usually used as a gasoline additive to increase octane and improve vehicle emissions. Bioethanol is widely used in the USA and in Brazil. Current plant design does not provide for converting the lignin portion of plant raw materials to fuel components by fermentation.

Biodiesel can be used as a fuel for vehicles in its pure form, but it is usually used as a diesel additive to reduce levels of particulates, carbon monoxide, and hydrocarbons from diesel-powered vehicles. Biodiesel is produced from oils or fats using Tran's esterification and is the most common biofuel in Europe.

In 2010, worldwide biofuel production reached 105 billion liters (28 billion gallons US), up 17% from 2009, [75] and biofuels provided 2.7% of the world's fuels for road transport. Global ethanol fuel production reached 86 billion liters (23 billion gallons US) in 2010, with the United States and Brazil as the world's top producers, accounting together for 90% of global production. The world's largest biodiesel producer is the European Union, accounting for 53% of all biodiesel production in 2010.[75] As of 2011, mandates for blending biofuels exist in 31 countries at the national level and in 29 states or provinces.[76] The International Energy Agency has a goal for biofuels to meet more than a quarter of world demand for transportation fuels by 2050 to reduce dependence on petroleum and coal.[77] The production of biofuels also led into a flourishing automotive industry, where by 2010, 79% of all cars produced in Brazil were made with a hybrid fuel system of bioethanol and gasoline.[78]

There are various social, economic, environmental and technical issues relating to biofuels production and use, which have been debated in the popular media and scientific journals. These include: the effect of moderating oil prices, the "food vs. fuel" debate, poverty reduction potential, carbon emissions levels, sustainable biofuel production, deforestation and soil erosion, loss of biodiversity, impact on water resources, rural social exclusion and injustice, shantytown migration, rural unskilled unemployment, and nitrous oxide (NO_2) emissions.

Types of Biofuel

First-generation biofuels

"First-generation" or conventional biofuels are made from sugar, starch, or vegetable oil. Such as Ethanol Fuel, Biodiesel, Green diesel, Biofuel gasoline, Vegetable oil fuel, Bio ethers (also referred to as fuel ethers or oxygenated fuels, Biogas, Syngas (Gasification), Solid biofuels etc.

Second-generation (advanced) biofuels

Second generation biofuels, also known as advanced biofuels, are fuels that can be manufactured from various types of biomass. Biomass is a wide-ranging term meaning any source of organic carbon that is renewed rapidly as part of the carbon cycle. Biomass is derived from plant materials but can also include animal materials.

First generation biofuels are made from the sugars and vegetable oils found in arable crops, which can be easily extracted using conventional technology. In comparison, second generation biofuels are made from lignocellulose biomass or woody crops, agricultural residues or waste, which makes it harder to extract the required fuel. A series of physical and chemical treatments might be required to convert lignocellulose biomass to liquid fuels suitable for transportation. [79][80]

Sustainable biofuels

Biofuels in the form of liquid fuels derived from plant materials are entering the market, driven mainly by the perception that they reduce climate gas emissions, and also by factors such as oil price spikes and the need for increased energy security. However, many of the biofuels that are currently being supplied have been criticized for their adverse impacts on the natural environment, food security, and land use. [81][82] In 2008, the Nobel-prize winning chemist Paul J. Crutzen published findings that the release of nitrous oxide (N_2O) emissions in the production of biofuels means that overall they contribute more to global warming than the fossil fuels they replace. [83]

The challenge is to support biofuel development, including the development of new cellulosic technologies, with responsible policies and economic instruments to help ensure that biofuel commercialization is sustainable. Responsible commercialization of biofuels represents an opportunity to enhance sustainable economic prospects in Africa, Latin America and Asia. [81][82][84]

According to the Rocky Mountain Institute, sound biofuel production practices would not hamper food and fiber production, nor cause water or environmental problems, and would enhance soil fertility. [85] The selection of land on which to grow the feed stocks is a critical component of the ability of biofuels to deliver sustainable solutions. A key consideration is the minimization of biofuel competition for prime cropland. [86][87]

1.2.8 Biomass

Biomass is organic matter derived from living, or recently living organisms. Biomass can be used as a source of energy and it most often refers to plants or plant-based materials which are not used for food or feed, and are specifically called lignocellulose biomass.[88] As an energy source, biomass can either be used directly via combustion to produce heat, or indirectly after converting it to various forms of biofuel.

Historically, humans have harnessed biomass-derived energy since the time when people began burning wood to make fire. [89] Even today, biomass is the only source of fuel for domestic use in many developing countries. Biomass is all biologically-produced matter based in carbon, hydrogen and oxygen. The estimated biomass production in the world is 104.9 pentagrams ($104.9 * 10^{15}$ g - about 105 billion metric tons) of carbon per year, about half in the ocean and half on land. [90]

Wood remains the largest biomass energy source today; [89] examples include forest residues (such as dead trees, branches and tree stumps), yard clippings, wood chips and even municipal solid waste. Wood energy is derived by using lignocellulose biomass (second-generation biofuels) as fuel. Harvested wood may be used directly as a fuel or collected from wood waste streams.

Type of Biomass conversion

Conversion of biomass to biofuel can be achieved by different methods which are broadly classified into: thermal conversion, chemical conversion, biochemical conversion, electrochemical conversion etc.

1.2.8.1 Biogas

Biogas typically refers to a mixture of different gases produced by the breakdown of organic matter in the absence of oxygen. Biogas can be produced from raw materials such as agricultural waste, manure, municipal waste, plant material, sewage, green waste or food waste. Biogas is a renewable energy source and in many cases exerts a very small carbon footprint.

Biogas can be produced by anaerobic digestion with anaerobic organisms, which digest material inside a closed system, or fermentation of biodegradable materials. [91]

Biogas is primarily methane (CH_4) and carbon dioxide (CO_2) and may have small amounts of hydrogen sulfide (H_2S), moisture and siloxanes. The gases methane, hydrogen, and carbon monoxide (CO) can be combusted or oxidized with oxygen. This energy release allows biogas to be used as a fuel; it can be used for any heating purpose, such as cooking. It can also be used in a gas engine to convert the energy in the gas into electricity and heat. [92]

Biogas can be compressed, the same way natural gas is compressed to CNG, and used to power motor vehicles. In the UK, for example, biogas is estimated to have the potential to replace around 17% of vehicle fuel. [93] Biogas can be cleaned and upgraded to natural gas standards, when it becomes bio-methane. Biogas is considered to be a renewable resource because its production-and-use cycle is continuous, and it generates no net carbon dioxide. Organic material grows, is converted and used and then regrows in a continually repeating cycle. From a carbon perspective, as much carbon dioxide is absorbed from the atmosphere in the growth of the primary bio-resource as is released when the material is ultimately converted to energy.

Composition

The composition of biogas varies depending upon the origin of the anaerobic digestion process. Landfill gas typically has methane concentrations around 50%. Advanced waste treatment technologies can produce biogas with 55%–75% methane, [94] which for reactors with free liquids can be increased to 80%-90% methane using in-situ gas purification techniques. [95] As produced, biogas contains water vapor. The fractional volume of water vapor is a function of biogas temperature; correction of measured gas volume for water vapor content and thermal expansion is easily done via simple mathematics [96] which yields the standardized volume of dry biogas.

In some cases, biogas contains siloxanes. They are formed from the anaerobic decomposition of materials commonly found in soaps and detergents. During combustion of biogas containing siloxanes, silicon is released and can combine with free oxygen or other elements in the combustion gas. Deposits are formed containing mostly silica (SiO2) or silicates (SixOy) andcancontain calcium, sulfur, zinc, phosphorus. Such white mineral deposits accumulate to a surface thickness of several millimeters and must be removed by chemical or mechanical means. Practical and cost-effective technologies to remove siloxanes and other biogas contaminants are available. [97]

For 1000 kg (wet weight) of input to a typical bio digester, total solids may be 30% of the wet weight while volatile suspended solids may be 90% of the total solids. Protein would be 20% of the volatile solids, carbohydrates would be 70% of the volatile solids, and finally fats would be 10% of the volatile solids.

Table 1: Composition of biogas from normally functioning digester [107]

Compound	Chemical Structure	Range (%)
Methane	CH_4	50-75
Carbon dioxide	CO_2	25-50
Nitrogen	N_2	0-10
Hydrogen	H_2	0.01-5
Oxygen	O_2	0.01-2
Water Vapor	H_2O	0-10
Hydrogen Sulphide	H_2S	10-30000 ppm
Amonia		0.01-2.5 mg/m^3

Energy content in biogas and other fuels

A typical normal cubic metre of methane has a calorific value of 9.97 kWh, while carbon dioxide has none at all. The energy content of biogas is therefore directly related to the methane content.

Energy content in different fuels:

- 1 Nm3 biogas (97 % methane) 9.67 kWh
- 1 Nm3 natural gas 11.0 kWh
- 1 litre petrol 9.06 kWh
- 1 litre diesel 9.80 kWh
- 1 litre E85 (ethanol) 6.60kWh

Production

Biogas can produce in many processes. Yield of biogas can affect by different factors. Especially it depends on different feedstock. The material that is used in anaerobic digestion is called feedstock. What goes into a digester determines what comes out, so careful choice of feedstocks is essential. The feedstock doesn't have to be waste, any biodegradable non-woody plant or animal matter is a suitable feedstock for a digester. However, anaerobic micro-organisms cannot break down lignin, the complex polymer that gives plants their strength, which means that wood products, paper and straw will slow the digester.

The yield of biogas from a particular feedstock will vary according to the following criteria.

- Dry matter content
- The energy left in the feedstock, if it has undergone prolonged storage it may already have begun to break down
- Length of time in the digester
- The type of AD plant and the conditions in the digester
- The purity of the feedstock
- Common feedstock streams are food and drink waste, processing residues, agricultural residues, crops, sewage sludge etc.

The table below shows data on the potential biogas yields of feedstock commonly used in anaerobic digestion (numbers given in italics are taken from an AD calculator[98] produced for NNFCC by The Andersons Centre, all other numbers are from Biogas from Energy Crop Digestion by the IEA). All figures are based on fresh weight unless stated.

Table 2: Data on the potential biogas yields of feedstock commonly used in AD

Feedstock	Biogas Yield (m3/t)	Feedstock	Biogas Yield (m3/t)
Cattle slurry	15-25 (10% DM)	Potatoes	276-400
Pig slurry	15-25 (8% DM)	Rye grain	283-492
Poultry	30-100 (20% DM)	Clover grass	290-390
Grass silage	160-200 (28% DM)	Sorghum	295-372
Whole wheat crop	185 (33% DM)	Grass	298-467
Maize silage	200-220 (33% DM)	Red clover	300-350
Maize grain	560 (80% DM)	Jerusalem artichoke	300-370
Crude glycerin	580-1000 (80% DM)	Turnip	314
Wheat grain	610 (85% DM)	Rhubarb	320-490
Rape meal	620 (90% DM)	Triticale	337-555
Fats	up to 1200	Oilseed rape	340-340
Nettle	120-420	Canary grass	340-430
Sunflower	154-400	Alfalfa	340-500
Miscanthus	179-218	Clover	345-350
Flax	212	Barley	353-658
Sudan grass	213-303	Hemp	355-409
Sugar beet	236-381	Wheat grain	384-426
Kale	240-334	Peas	390
Straw	242-324	Ryegrass	390-410
Oats grain	250-295	Leaves	417-453
Chaff	270-316	Fodder beet	160-180

A comprehensive list of biogas yield data is available via the CROPGEN Database. The full database contains data for 729 different feedstocks and is available to download [99] in Access format from CROPGEN here (4th item on the table). Here it will also find a useful on-farm energy and emissions calculator [100] which can be used for calculating the energy requirements and GHGs for crop production and potential energy generation using an on-farm AD plant. [101]

Here the basic step of biogas production process has been given below.

Anaerobic Digestion

Anaerobic digestion (AD), as a renewable energy technology, is the harnessing of natural biological processes to use available biomass (e.g. food wastes, animal slurries and crop feedstock) to produce renewable methane, which can then be used to produce electricity, heat or upgraded for vehicle fuel and injection to gas grid.

Feedstock

Organic feedstock is very flexible, ranging from farm manures and crops, to sewage sludge and catering wastes and food wastes (including uncooked and cooked food, including meat products). Feedstock usually has a high moisture content making them more suited to the AD process.

Pre-Treatment

Many AD processes require the feedstock to undergo a process of treatment before entering the now. This will often take the form of maceration which reduces the particle size normally to at least 12mm. This helps to ensure that the material is fluid enough to be pumped through the process and also it also increases the surface area of the material for the bacteria to act upon. There can also be a screening phase which will remove unwanted materials such as metals, plastics or stone, and will protect downstream treatment processes. Where appropriate, pre-treatment also includes pasteurization.

Pasteurization

Most AD facilities will have a pasteurization phase to kill harmful pathogens such as salmonella and E.Coli. It can be before or after digestion and will normally consist of raising the temperature of the material to 70oC for 1 hour. This is often a requirement for AD plants using any animal byproducts as a feedstock or for those plants certified under the Biofertiliser Certification Scheme to PAS110 and the ADQP.

Digestion and Production of Biogas

The pre-treated organic feedstock is then placed in sealed tanks where naturally occurring micro-organisms break down the organic materials resulting in the release of gas that is around 60% methane (CH4) and 40% carbon dioxide (CO2); though the mixture of the gas can depend on the feedstock put into the digester. The methane produced can then be used in to generate renewable electricity and heat. Normally a biogas engine can gain an electrical conversion efficiency of up to 35% with the remainder being available as heat. [102]

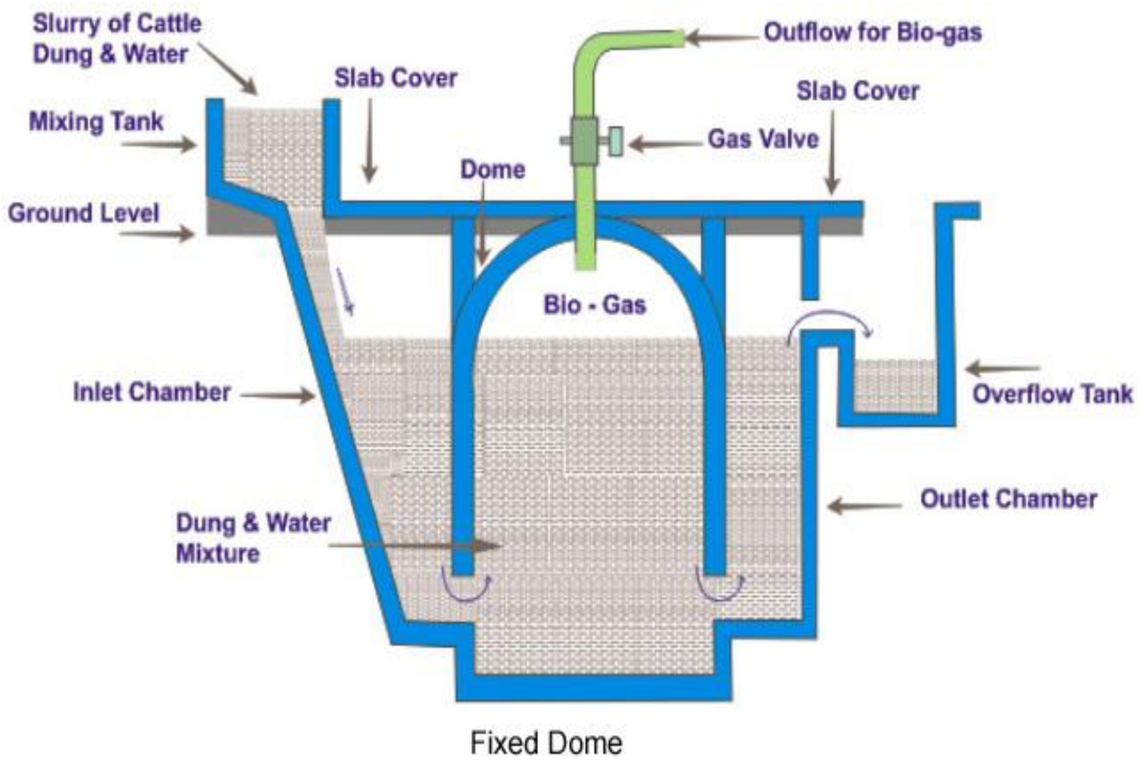

Figure 1: Fixed dome type biogas plant [105]

In addition to the production of power and heat, the left over organic material (digestive) is rich in nutrients and can be used as a substitute to chemical based fertilizers.

The energy in biogas can be used in several ways. Such as heat production, electricity produc tion, combined heat and power transport fuel, injection in to the main electricity or gas grid after upgrading etc.[102]

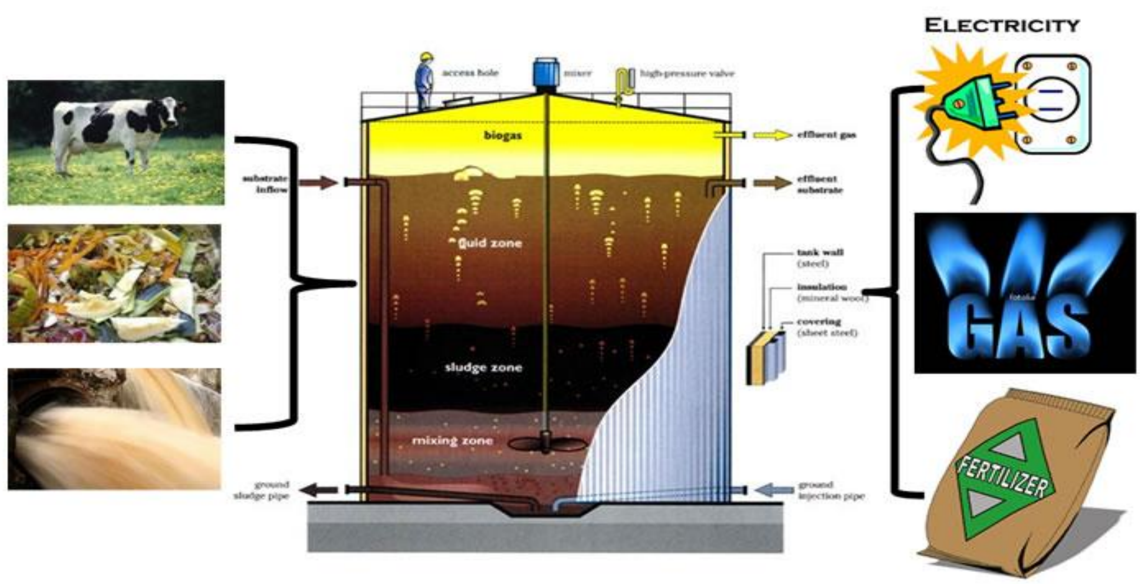

Figure 2: Biogas plant and different type of energy production [106]

There are two key processes: mesophilic and thermophilic digestion which is dependent on temperature. In experimental work at University of Alaska Fairbanks, a 1000-litre digester using psychrophiles harvested from "mud from a frozen lake in Alaska" has produced 200–300 liters of methane per day, about 20%–30% of the output from digesters in warmer climates. [103]

Use of biogas

While most large farms use their biogas for heat and power, it is worthwhile to consider all the options before deciding which path to take, including direct sale of biogas to an off-farm buyer.

Raw animal manure biogas contains 55 to 65% methane (CH4), 30 to 45% carbon dioxide (CO2), traces of hydrogen sulfide (H2S) and hydrogen (H2), and fractions of water vapor. For the anaerobic digestion of sludge or landfill processes, traces of siloxanes may also be found in biogas. These siloxanes mainly originate from silicon-containing compounds widely used in various industrial materials or frequently added to consumer products such as detergents and personal care products. This article will not address the cleanup of biogas of siloxanes.

Biogas is about 20% lighter than air and has an ignition temperature in the range of 650 to 750 degrees C. (1,200-1,380 degrees F.). It is an odorless and colorless gas that burns with a clear blue flame similar to that of natural gas. However, biogas has a calorific value of 20-26 MJ/m3 (537-700 Btu/ft3) compared to commercial quality natural gas' caloric value of 39 MJ/m3 (1,028 Btu/ft3).

Biogas can potentially be used in many types of equipment, including:

- Internal Combustion (Piston) Engine – Electrical Power Generation, Shaft Power
- Gas Turbine Engine (Large) – Electrical Power Generation, Shaft Power
- Microturbine Engine (Small) – Electrical Power Generation
- Stirling Heat Engine – Electrical Power Generation
- Boiler (Steam) Systems
- Hot Water Systems
- Process Heaters (Furnaces)
- Space or Air Heaters
- Gas Fired Chiller - Refrigeration
- Absorption Chiller - Refrigeration
- Combined Heat and Power (CHP) - Large and Small Scale – Electrical Power and Heat
- Fuel Cells – Electrical Power, Some Heat

There are a variety of end uses for biogas. Except for the simplest thermal uses such as odor flaring or some types of heating, biogas needs to be cleaned or processed prior to use. With appropriate cleaning or upgrade, biogas can be used in all applications that were developed for natural gas.

The three basic end uses for biogas are:

- Production of heat and steam
- Electricity generation
- Vehicle fuel

Biogas Cleanup or Upgrading

Biogas cleaning is important for two reasons: (1) to increase the heating value of biogas and (2) to meet requirements for some gas appliances (engines, boilers, fuel cells, vehicles, etc.). Desired biogas cleaning or upgrading purposes are summarized in Figure 1. "Full treatment" implies that biogas is cleaned of CO2, water vapor, and other trace gases, while "reforming" is conversion of methane to hydrogen. [104]

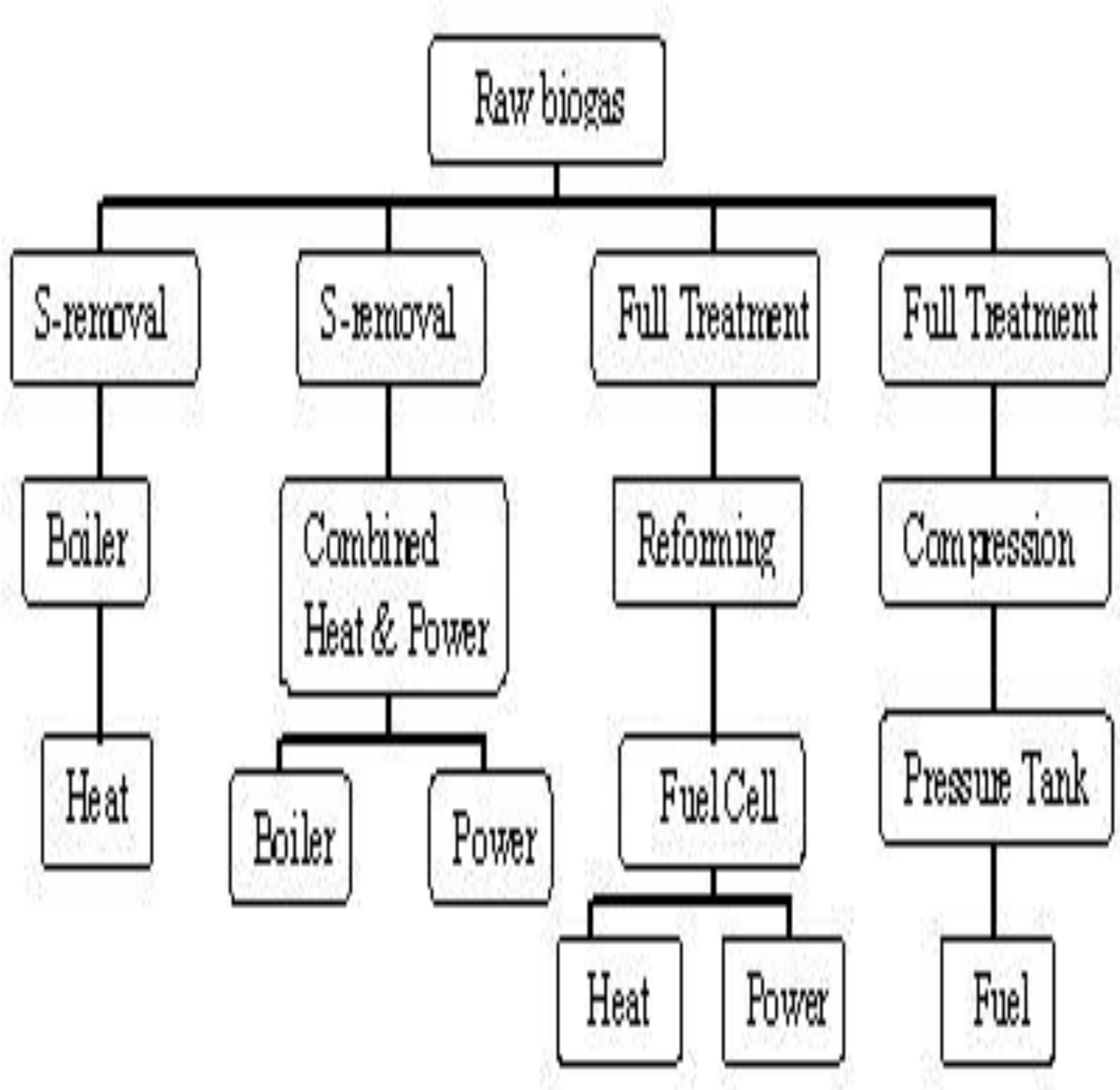

Figure 3: Alternative biogas utilization and required cleanup [104]

For some utilization of biogas the amount of required components needs to remove are given below:

Table 3: Required component of biogas that required reducing for different application of biogas [107]

Application	H_2S	CO_2	H_2O	Siloxanes
Boiler	<1000 ppm	No	No	No
Cooker	Yes	No	No	No
Stationary Engine	<250 ppm	No	No	Yes
Vehicles Fuel	Yes	Recommended	Yes	No
Natural Gas Grid	Yes	Yes	Yes	Eventually

1.3 Petition of problem:

Bangladesh is mainly agricultural country with small industrialized area. It has area 147,570 km^2 [108] with population density 1113.98/km^2. [109] Due to this it required a large amount of energy. But its economic condition is not enough strong to yield and endure energy for extent population and blooming economy. Yet there is no perceptible step has been taken to switching from traditional fossil fuel to biogas other renewable energy such as solar energy, hydropower, nuclear energy, tidal power, wave energy, wind etc. Among all renewable resources biogas scheme is low cost and compatible with agriculture base society and small industrialized system. Biogas has all convenience to meet our required energy both in town and rural areas. We just need to take necessary steps to execute biogas scheme in different way in rural and town area. But it is matter of great regret that it is not popular in rural communities and cannot imagine in town area. Though residents of town face a great crisis of energy specially gas, they pay spontaneously pay about TK1400-4000 per LPG cylinder with its own disadvantage and risk. However they are not desire adopt low cost, risk free and environment amicable portable or general biogas scheme. However, in this thesis I am trying my best to pursue the reason why people do not prefer biogas as their first choice and as well as their experience on biogas.

1.4 Hypothesis

The main argument of this thesis is to assess the experience of people of Bangladesh and other counties with biogas. This study is trying to find out reason why people do not use biogas as expected level though maximum facilities such as raw material to produce gas cost efficient, green energy etc. In addition to gives huge amount of organic fertilizer as byproduct which is very important and necessary for our agricultural economy. With the respiratory problem, high cost, non-efficient, no environment friendly the rural people adopt traditional energy system such as firewood, kerosene, cow dung, straw, waste of crops and grains etc. Still they have opportunity to use clean and cost efficient biogas not only for cooking but also for lighting and other utilization and byproduct can use for organic fertilizer. These also flourish them with excellent health and economy.

1.5 Purpose of study

The principal purpose of this study is to accumulation of knowledge about the experience of biogas of the people at both town and village in Bangladesh as well as in other countries.

The secondary purpose is to find out the barriers about why people do not prefer biogas as their first choice for energy source among all type of energy source.

1.6 Self-defense

The study is precise on this basis that it will introduce the experience of the people of Bangladesh and other countries with biogas.

Secondly it will support to find the significant cause why biogas is not preferred in first choice by people of Bangladesh. As financial condition of Bangladesh does not support the government to extend gird power line in every part of the country. It is also not possible to support the entire farmer by providing subsidy [110] on fertilizer equally. Further government cannot provide environment amicable waste management. Hence biogas can be an effective source of energy, organic fertilizer and waste management. Hence if it is possible to trace the problem of people for what they do not adopt biogas in a large scale and then these problems can resolve easily. Consequently it will assist people to build a proper healthy life and economy which will boost the blooming economy of Bangladesh.

1.7 Thesis layout

The framework of this thesis will comprise of five key chapters.

Chapter One

The first chapter will introduce the study, the problem that has necessitated the study. It will also touch on what this study hopes to attain and the justification as well as an overview of the layout of the study.

Chapter Two

This chapter will discuss the methodology of the data collection. It will touch on the sampling method, research instruments and the techniques that will be used to analyze and summarize the data. In addition to the above, it will raise issues about the validity of the data collected and the limitations that may have risen due to the method used to collect the data and other problem. This structure will help set the ball rolling for the data analysis in the chapters to follow.

Chapter Three

Chapter three presents the review on experience of biogas and level of energy use from biogas in the other countries for both developed and developing countries. It also presents lessons that were learnt by them. This is done with the intention of highlight the difference of energy use level, propagation of biogas between developed and developing countries. Hence to find out important issues that has been faced in case of propagation of biogas in the developing world. The countries that will be review are Germany, United Kingdom, Austria, Sweden and United States of America from developed world and China, India, Nigeria and Ethiopia from developing world.

Chapter Four

This chapter presents the data collected during fieldwork and literature study is processed, classified, analyzed and summarized to make them valuable information.

Chapter Five

This chapter is the discussion and concluding chapter. It will be devoted to conclusions that will be drawn from the discussions that will follow from the data analysis. These conclusions will facilitation anyone or any institution to schedule policy for the biogas sector.

1.8 The study area

The principal purpose of this study is to hit off or have knowledge about the experience on biogas of people at both town and village in Bangladesh as well as other countries. Due various limitations it is not possible to conduct field work at whole study area. But to make this report authentic and valuable filed work conduct as many place as possible. The other areas of this study completed by depend on literature study on different article on various topics.

Opportunities are only available to conduct field work in Bangladesh. In Bangladesh the areas where field work are conducted

- Dhaka Metro
- Chittagong Metro
- Chandanish
- Satkania
- Lohagara
- Chakaria
- Coxs Bazar.

Location map where field work are conducted given below

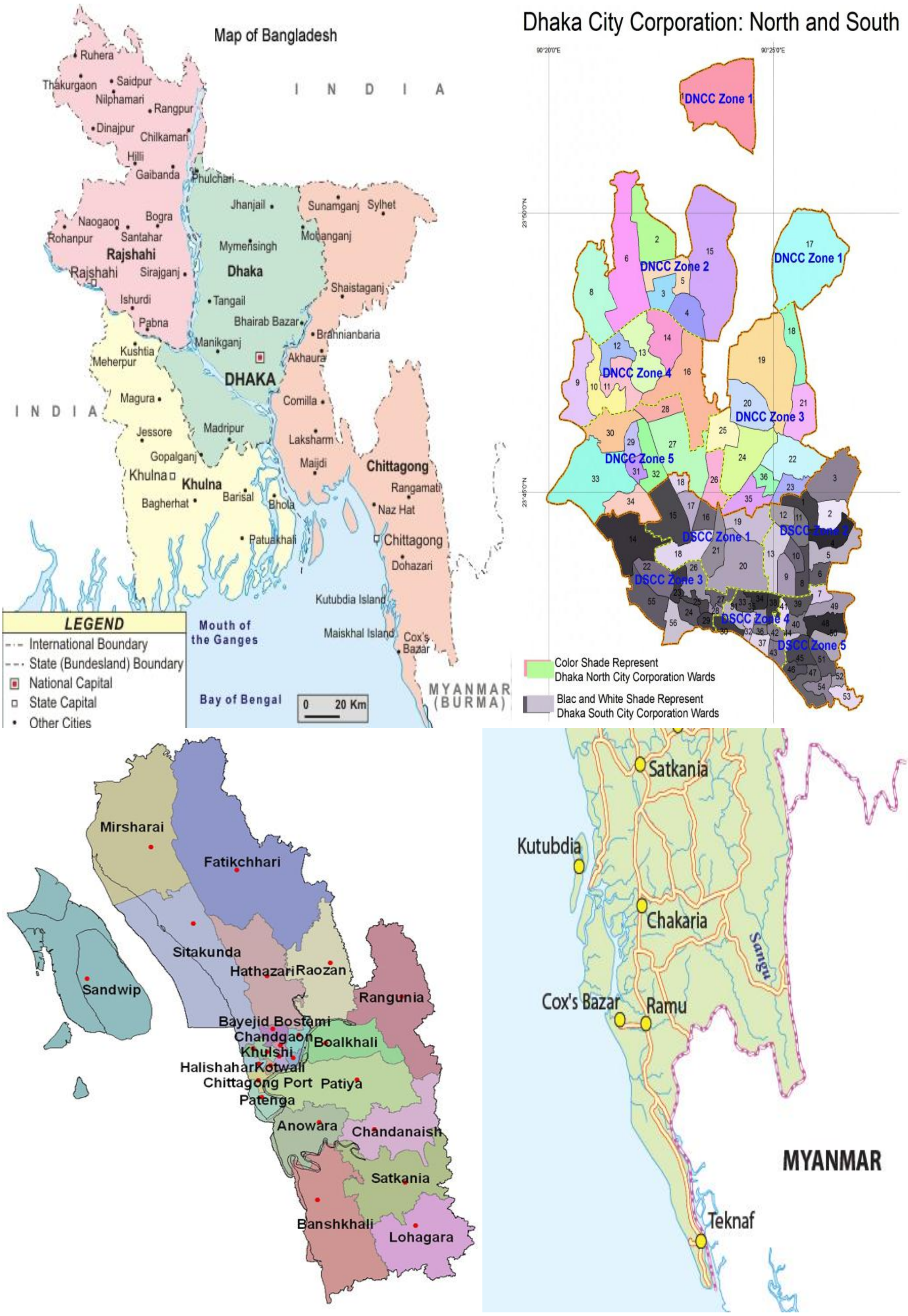

Figure 4: Location map of Bangladesh [111], Dhaka metro [112], Chittagong [113] (Chandanish, Satkania, Lohagara, Chakaria), Cox's Bazar [113]

There is no opportunity to conduct field work in other countries due to various limitations. Hence this study is depending on literature study for the other countries. Depend on literature study the areas are

- **Developed World**
    - United States of America (USA)
    - European Union
        - Germany
        - United Kingdom
        - Austria
        - Sweden
- **Developing World**
    - China
    - India
    - Nigeria
    - Ethiopia

Location map where depend on literature study are given below

Figure 5: Location Map of United States of America [119]

Figure 6: Location Map of Europe [114], Germany [115], United Kingdom [116], Austria [117] and Sweden [118]

Figure 7: Location Map of China [120], India [121], Nigeria [122] and Ethiopia [123]

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Chapter Two

Research Methodology

2.1 Introduction

According to Goddard & Melville (2004), answering unanswered questions or exploring which currently not exist is a research. A broad definition of research is given by Godwin Colibao - "In the broadest sense of the word, the definition of research includes any gathering of data, information and facts for the advancement of knowledge."[1] Another definition of research is given by Creswell who states that - "Research is a process of steps used to collect and analyze information to increase our understanding of a topic or issue". It consists of three steps: Pose a question, collect data to answer the question, and present an answer to the question. [2] Research methodology defines as the process used to collect information and data for the purpose of making business decisions. The methodology may include publication research, interviews, surveys and other research techniques, and could include both present and historical information. [3]

For the recruitment and processing of the data to appeared as proof of this thesis, I present and hit off all the method that were consider and bring to bear in this chapter. Here I also involve the research design adopted, the target area, the target population, sampling technique used and the instruments appliance to process the data that obtain in research.

2.2 Types of research method

The Merriam-Webster Online Dictionary defines research in more detail as "a studious inquiry or examination; especially investigation or experimentation aimed at the discovery and interpretation of facts, revision of accepted theories or laws in the light of new facts, or practical application of such new or revised theories or laws".[4]

There are two types of research which can be done to develop a thesis or dissertation:

Practical Research: The practical approach consists of the empirical study of the topic under research and chiefly consists of hands on approach. This involves first hand research in the form of questionnaires, surveys, interviews, observations and discussion groups. [5]

Theoretical Research: A non-empirical approach to research, this usually involves perusal of mostly published works like researching through archives of public libraries, court rooms and published academic journals.[6]

From the other point of view research are four types. They are

- Descriptive vs. Analytical
- Applied vs. Fundamental
- Quantitative vs. Qualitative
- Conceptual vs. Empirical

After research methodology are combination of different type of research method and research techniques. Where research techniques refer to the behavior and instruments we use in performing research operations such as making observations, recording data, techniques of processing data and the like. On the other hand research methods refer to the behavior and instruments used in selecting and constructing research techniques. The relation between method and techniques are given below.

Table 4: The relation between method and techniques

Type	*Methods*	*Techniques*
1. Library Research	(i) Analysis of historical records	Recording of notes, Content analysis, Tape and Film listening and analysis.
	(ii) Analysis of documents	Statistical compilations and manipulations, reference and abstract guides, contents analysis.
2. Field Research	(i) Non-participant direct observation	Observational behavioural scales, use of score cards, etc.
	(ii) Participant observation	Interactional recording, possible use of tape recorders, photographic techniques.
	(iii) Mass observation	Recording mass behaviour, interview using independent observers in public places.
	(iv) Mail questionnaire	Identification of social and economic background of respondents.
	(v) Opinionnaire	Use of attitude scales, projective techniques, use of sociometric scales.
	(vi) Personal interview	Interviewer uses a detailed schedule with open and closed questions.
	(vii) Focussed interview	Interviewer focuses attention upon a given experience and its effects.
	(viii) Group interview	Small groups of respondents are interviewed simultaneously.
	(ix) Telephone survey	Used as a survey technique for information and for discerning opinion: may also be used as a follow up of questionnaire.
	(x) Case study and life history	Cross-sectional collection of data for intensive analysis, longitudinal collection of data of intensive character.
3. Laboratory Research	Small group study of random behaviour, play and role analysis	Use of audio-visual recording devices, use of observers, etc.

From what has been sated above, we can say that methods and techniques are taken as interchangeable. Hence research methodology is a way to systematically solve the research problem. [7]

Hither a flowchart of classifying methodology attach in the below:

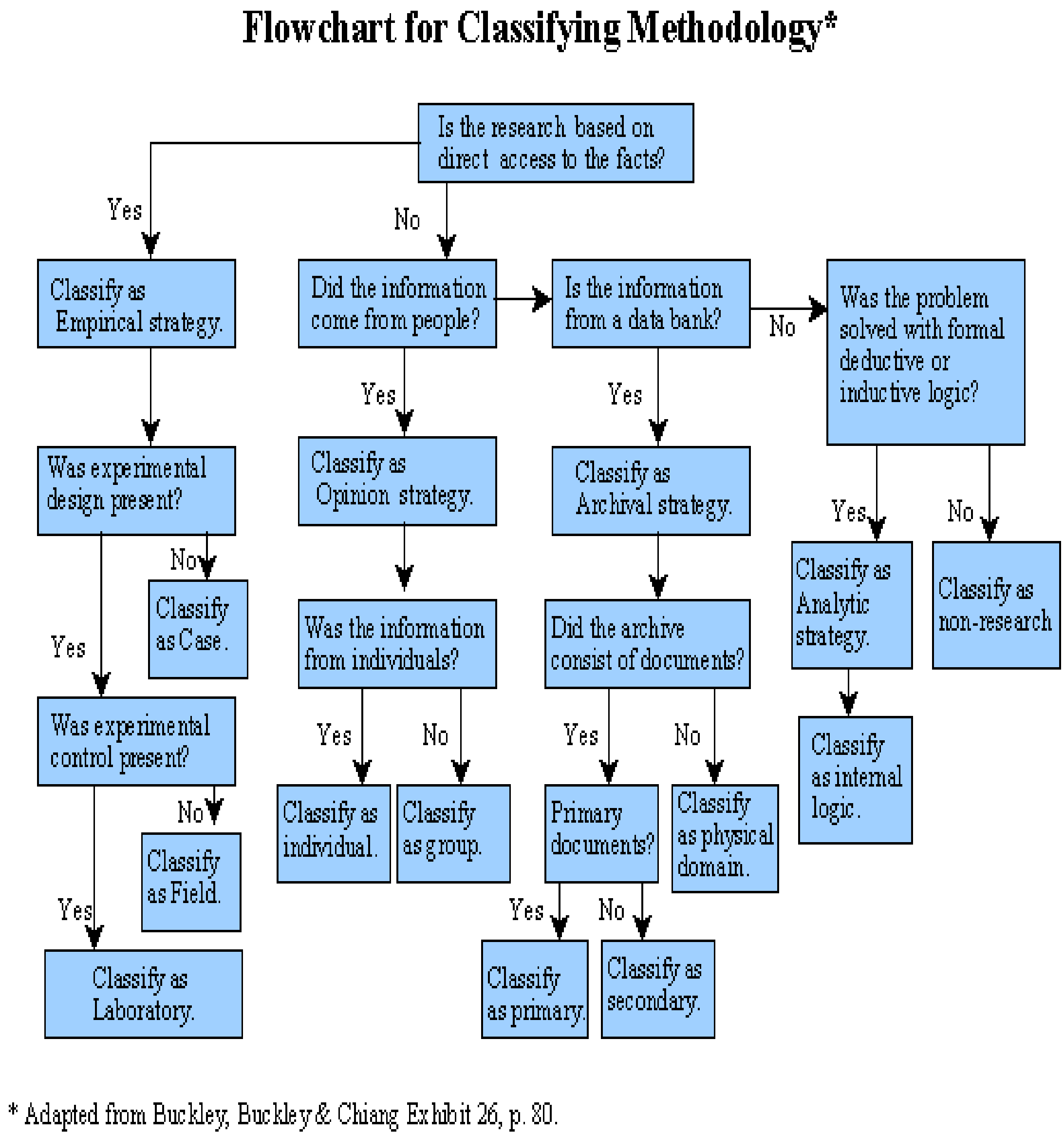

Figure 8: Flowchart for Classifying Methodology

From the different type methodology I have been stated above this thesis has been commenced as a combination of library study, literature study and field study of different information, articles which deal with renewable energy utilization in different sectors. Here some article also deal with related issues such as weather, climate, deforestation, oceanography etc.

2.3 Sample Size and Sampling Procedure

In all a total of sixteen respondents were selected for this study. (Alreck and Settle 1985), advocate that a sample should represent a tenth of the entire population being studied. However (Fraenkel and Wallen 2003), on the other hand emphasize that the best sample size is one that is large enough for the researcher to obtain the kind of data that expresses the diversity of the experiences for the study. As mentioned before, this study is more about representing the diversity of experiences as such a large sample was not focus but rather a diverse sample to represent variety.

The procedures used to decide the sample size include purposive and snowball sampling techniques. Purposive sampling involves selecting the sample that can give the most information for the study. In the case of this study purposive sample used to select the people who have actually encountered and experienced biogas and also who have no experience with biogas.

The snowballing on the other hand is where the researcher is referred to other sources of information and resource persons by the initial respondents. In fact most of the respondents for this study came about through snowball sampling technique since they were recommended by members of my purposive sample.

Table 5: Sampling distribution

Area	Number of males interviewed	Number of females interviewed	Number of total people interviewed
Dhaka metro	12	7	19
Chittagong metro	8	3	11
Chandanish	1	1	2
Satkania	2	1	3
Lohagara	1	0	1
Chakaria	3	2	5
Coxsbazar	2	0	2
Total	29	14	43

Source: Fieldwork

2.4 The Interview Process

The aim of the interviews conducted was to find diversity of experiences with biogas among the people of Bangladesh. Rather than administering a questionnaire an interview guide was used so as to bring out the actual perceptions of the interviewees and also to explore other issues that the questionnaire may not have covered. As mentioned earlier, two different interview guides were used, one was directed at those who have ever used biogas and the other was for those who have never used biogas. Though the interviews were scheduled, they were conducted in a very informal and relaxed manner in order to keep the situation natural and friendly.

According to Seidel (1998), in-depth interviewing helps the researcher to understand better, the experiences of the respondents and the meanings that the respondents attach to their experiences. The semi structured nature of the interviews therefore equipped me with the flexibility needed to probe further where necessary and to make adjustments to the questions asked when the situation demanded.

This is not to say that interviews have no weaknesses because the process of interviewing can be very time consuming and often interviews exceed their scheduled duration.

Secondly the problem of language barrier is often experienced by researchers but in the case of this study researcher had in-depth knowledge of the local language of the selected area and therefore had no problem communicating with my respondents. Many researchers caught in this web try to employ the services of one of the locals as a translator but many a time, conveying the true meaning of sentences can be more complex than imagined especially when the translator does not understand fully the real meaning of the questions.

As a researcher faced the problem of wrong impressions perceived by the respondents or created by the researcher. When respondents perceive the researcher as a personality they cannot trust, information is very much withheld. On the other hand when respondents view the researcher as a source of help they tend to exaggerate the information.

In many case researcher experienced the modern situation during the interview process among rural area. Most of the people perceived me to be a government agent who may be coming to help revive the biogas program that was brought to an abrupt end. As a result researcher did sense that most of their response to my questions had some element of exaggeration. With experience and proper explanation to the respondents (which researcher vehemently did) this particular problem can be overcome.

Each interview was prescheduled and the consent of the respondents sought before the interview was carried out. The questions were taken from the appropriate interview guide but follow up questions varied depending on the responses researcher received from my interviewees.

Apart from the people especially women all the respondents interviewed refused to be recorded on digital recorder. So in most of the case, researcher records the required data in manually.

2.5 Data Gathering Techniques

From the above mentioned techniques it is try best to gather expected and original data. To get the actual data sometime sometimes needs to take the help of sixth scenes by observing the body language such as respondent’s countenance, enthusiasm or hesitance of people. Hence the data collected for this study was gathered from people through formal and informal interviews as well as observations.

The collected data is classified by following standard and suitable way that it needs to complete this study and made this study authentic and valuable.

2.6 Data Analysis

Data analysis involves all processes and procedure whereby we move from data collected to some form of explanation, understanding, interpreting and basically making sense out of the data (Strauss and Cobin 1990). The processes are; writing, coding into themes and then finding out what available literature there is regarding the research topic.

Remaining open minded is also necessary when trying to uncover what functional relations there are between observations. Strauss and Cobin suggest constant comparison as a way for the researcher to remain open minded. One way of doing this is to look at the phenomena in all ways that other people might see it, even perceptions that may be completely outside the study in order to come out with a holistic view point.

However it remains a fact that in social research remaining totally objective is very difficult since all humans have their personal opinions and have been socialized differently. As a result of this, social researchers concern themselves more with trying to strengthen their hypothesis rather than trying to establishing truth (Willig 2001).

2.7 Limitations of the Study

No research design is perfect, (Patton 2002) and it applies to this study as well. Several limitations can be pointed out in this study but then the design of the research is subject to the kind of data that is being sought after for the study.

To get wide variety of experience of people in biogas both rural and urban people are focuses. For flexibility researcher select that area which is known from childhood. Researcher knows the local language, culture etc. Hence the main weakness of this investigation is that it conducted in a small selected area.

Since it was a survey of the users and the source of primary data and information was mainly the household survey. Hence there was no actual measurement and as far as quantifiable data and information were concerned, recall method was used, which may not be very exact. It is also a weakness of this study.

On the other hand the perspectives and direction of the study is based on interviews with limited number of people. This is another noticeable weakness of this study. However as explained earlier, this study is not to represent the views and experience of all but rather to understand the dynamics surrounding biogas dissemination and use in rural and urban area of Bangladesh.

Finally time and financial constraints and a short period of timeframe did not give researcher the flexibility to visit as many rural and urban communities as would have been desired. Ideally researcher could have gone to different regions in Bangladesh and gained additional experiences and information. These limitations however do not affect the authenticity of the study and so a lot of lessons can still be learnt from the outcome of this study.

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Chapter three

Review on Experience of Biogas in the Other Countries.

3.1 Introduction

Biogas technology has been used all over the world for several decades with some of the dissemination programs being more successful than others. This chapter attempts to take a critical look at efforts by some countries to introduce biogas technology to their communities.

3.2 Developed world

Under the section of developed I attempt to take review of countries in European Union and USA. They developed their biogas production efficiency produce biogas from different feedstock but before that they start use of biogas for several decades.

3.2.1 United States of America

With the many benefits of biogas, it is starting to become a popular source of energy and is starting to be used in the United States more. In 2003, the United States consumed 147 trillion BTU of energy from "landfill gas", about 0.6% of the total U.S. natural gas consumption. [26] Methane biogas derived from cow manure is being tested in the U.S. According to a 2008 study, collected by the Science and Children magazine, methane biogas from cow manure would be sufficient to produce 100 billion kilowatt hours enough to power millions of homes across America. Furthermore, methane biogas has been tested to prove that it can reduce 99 million metric tons of greenhouse gas emissions or about 4% of the greenhouse gases produced by the United States. [27]

In Vermont, for example, biogas generated on dairy farms was included in the CVPS Cow Power program. The program was originally offered by Central Vermont Public Service Corporation as a voluntary tariff and now with a recent merger with Green Mountain Power is now the GMP Cow Power Program. Customers can elect to pay a premium on their electric bill, and that premium is passed directly to the farms in the program. In Sheldon, Vermont, Green Mountain Dairy has provided renewable energy as part of the Cow Power program. It started when the brothers who own the farm, Bill and Brian Rowell, wanted to address some of the manure management challenges faced by dairy farms, including manure odor, and nutrient availability for the crops they need to grow to feed the animals. They installed an anaerobic digester to process the cow and milking center waste from their 950 cows to produce renewable energy, a bedding to replace sawdust, and a plant-friendly fertilizer. The energy and environmental attributes are sold to the GMP Cow Power program. On average, the system run by the Rowells produces enough electricity to power 300 to 350 other homes. The generator capacity is about 300 kilowatts. [28]

In Hereford, Texas, cow manure is being used to power an ethanol power plant. By switching to methane biogas, the ethanol power plant has saved 1000 barrels of oil a day. Over all, the power plant has reduced transportation costs and will be opening many more jobs for future power plants that will rely on biogas. [29]

In Oakley, Kansas, an ethanol plant considered to be one of the largest biogas facilities in North America is using Integrated Manure Utilization System "IMUS" to produce heat for its boilers by utilizing feedlot manure, municipal organics and ethanol plant waste. At full capacity the plant is expected to replace 90% of the fossil fuel used in the manufacturing process of ethanol.[30][31]

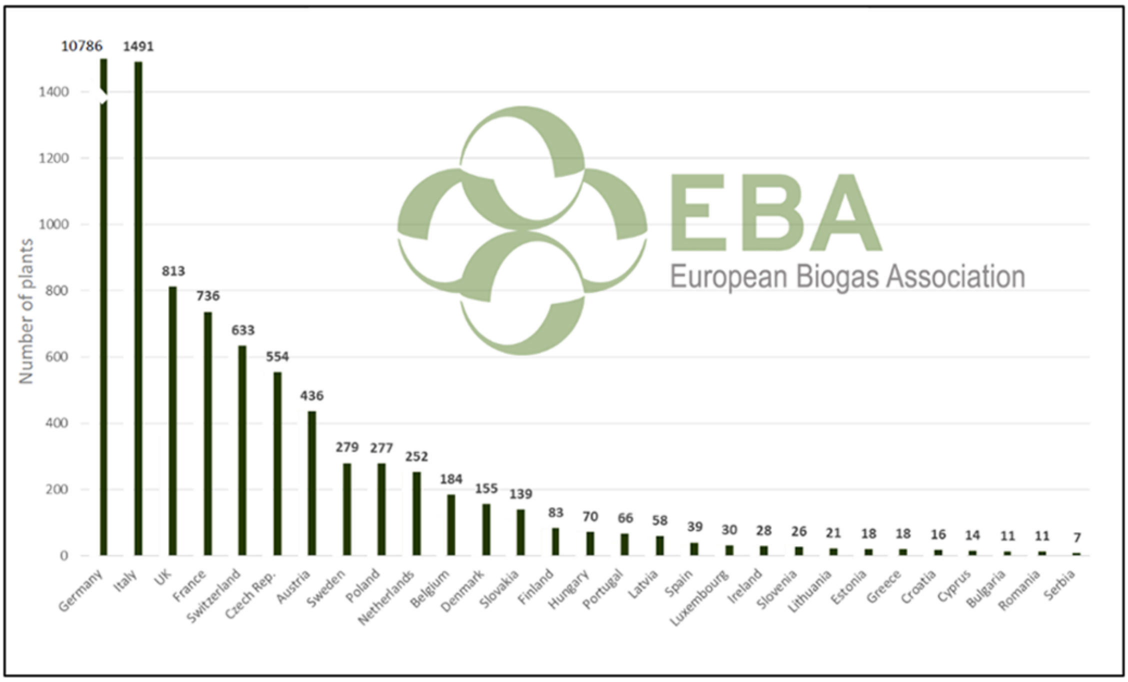
Figure 9: Biogas plant map of United States of America [32]

3.2.2 European Union

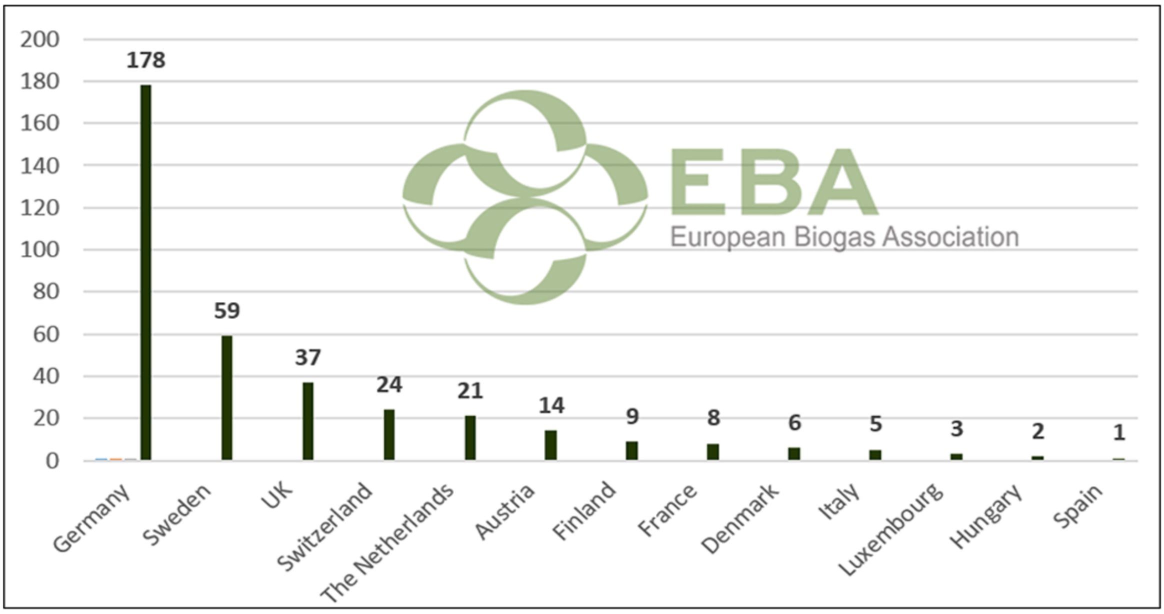
In European Union the level of development varies greatly. While countries such as Germany, United Kingdom, Austria and Sweden are advanced in their use of biogas, there is a vast potential for this renewable energy source in the rest of the continent, especially in Eastern part of Europe. The European Union has legislation regarding waste management and landfill sites called the Landfill Directive. Countries such as the United Kingdom and Germany now have legislation in force that provides farmers with long-term revenue and energy security. [1]

Initiated by the events of the gas crisis in Europe during December 2008, it was decided to launch the EU project "SEBE" (Sustainable and Innovative European Biogas Environment) which is financed under the CENTRAL program. The goal is to address the energy dependence of Europe by establishing an online platform to combine knowledge and launch pilot projects aimed at raising awareness among the public and developing new biogas technologies. [2]

In February 2009, the European Biogas Association (EBA) was founded in Brussels as a non-profit organization to promote the deployment of sustainable biogas production and use in Europe. EBA's strategy defines three priorities: establish biogas as an important part of Europe’s energy mix, promote source separation of household waste to increase the gas potential, and support the production of bio methane as vehicle fuel. In July 2013, it had 60 members from 24 countries across Europe. [3]



17 240 biogas plants in Europe (31/12/2014)
Total installed capacity of 8 293 MW_{el}



367 biomethane AD plants in Europe (31/12/2014)
Total upgrading capacity 310 thousands m3/h of raw biogas

Figure 10: Graph on Biogas plant capacity in Europe courtesy EBA

3.2.2.1 Germany

Many European countries have established favorable conditions for uses of biogas using different technologies. Germany has a leading role in Europe. Germany is Europe's biggest biogas producer [4] and the market leader in biogas technology. [5] In 2010 there were 5,905 biogas plants operating throughout the country: Lower Saxony, Bavaria, and the eastern federal states are the main regions. [6] Most of these plants are employed as power plants. Usually the biogas plants are directly connected with a CHP which produces electric power by burning the bio methane. The electrical power is then fed into the public power grid. [7] In 2010, the total installed electrical capacity of these power plants was 2,291 MW. [6] The electricity supply was approximately 12.8 TWh, which is 12.6% of the total generated renewable electricity. [8]

Biogas in Germany is primarily extracted by the co-fermentation of energy crops (called 'NawaRo', an abbreviation of nachwachsende Rohstoffe, German for renewable resources) mixed with manure. The main crop used is corn. Organic waste and industrial and agricultural residues such as waste from the food industry are also used for biogas generation. [9]In this respect, biogas production in Germany differs significantly from the UK, where biogas generated from landfill sites is most common. [4]

Biogas production in Germany has developed rapidly over the last 20 years. The main reason is the legally created frameworks. Government support of renewable energy started in 1991 with the Electricity Feed-in Act. This law guaranteed the producers of energy from renewable sources the feed into the public power grid, thus the power companies were forced to take all produced energy from independent private producers of green energy. [10] In 2000 the Electricity Feed-in Act was replaced by the Renewable Energy Sources Act (EEG). This law even guaranteed a fixed compensation for the produced electric power over 20 years. The amount of around 8 ¢/kWh gave farmers the opportunity to become energy suppliers and gain a further source of income. [9]

The German agricultural biogas production was given a further push in 2004 by implementing the so-called NawaRo-Bonus. This is a special payment given for the use of renewable resources, that is, energy crops. [11] In 2007 the German government stressed its intention to invest further effort and support in improving the renewable energy supply to provide an answer on growing climate challenges and increasing oil prices by the ‘Integrated Climate and Energy Program’.

This continual trend of renewable energy promotion induces a number of challenges facing the management and organization of renewable energy supply that has also several impacts on the biogas production. [12] The first challenge to be noticed is the high area-consuming of the biogas electric power supply. In 2011 energy crops for biogas production consumed an area of circa 800,000 ha in Germany. [13] This high demand of agricultural areas generates new competitions with the food industries that did not exist hitherto. Moreover, new industries and markets were created in predominately rural regions entailing different new players with an economic, political and civil background. Their influence and acting has to be governed to gain all advantages this new source of energy is offering. Finally biogas will furthermore play an important role in the German renewable energy supply if good governance is focused. [12]

From 2015, the situation could change due to a revision of the recycling law, which would make the separate collection of bio waste from households mandatory. Accordingly, up to four million tons of household and kitchen waste could be additionally collected and fermented in biogas plants. [14]

The German experience is particularly instructive for all. Since the introduction of Feed-In Tariffs for biogas in Germany, over 7,000 biogas projects have been developed, generating over 2700MW of electricity. Germany is on target to generate 17% of total power from biogas. Ontario has targeted 12% of electrical power from all renewables combined by 2025. The biogas industry has contributed $1 billion of direct investment in Germany's economy and has created over 46,000 jobs. By 2020, Germany is anticipating $10.5 billion in investment, with the creation of 85,000 jobs. [15]

Figure 11: Biogas plant map of Germany [16]

Electricity/Heat

With 20 MW electric powers fed into the grid the new biogas park in Pekun, north-eastern Germany, is currently the world's largest biogas installation. The park consists of 15 hectares and 40 standardized modules with a capacity of 500 kWhel each and it can be enlarged if necessary. 84.000 t of manure and maize from 6000 hectares in immediate vicinity will be processed every year. For a plant of this size, the harvesting, feedstock delivery and storage have to be optimized in order to guarantee a steady supply of feedstock.

Bio methane injection

The upgrading of biogas to natural gas standard is more economical in larger installations – the bigger the better.

Example: Schwandorf plant (e-on Bioerdgas)

Input material:	80.000 t/year of crops
Production of raw biogas:	2.000m^3/h
Bio methane production:	90 Mio. KWh/year
Gas quality:	11.1kWh/m^3 (H-Gas)
Investment:	18 M Euro

A new development is the cooperation of small, decentralized biogas plants that send their raw biogas via pipes to a central upgrading facility, thus significantly reducing feedstock transportation and upgrading costs. [17]

3.2.2.2 United Kingdom

As of September 2013, there are about 130 non-sewage biogas plants in the UK. Most are on-farm, and some larger facilities exists off-farm, which are taking food and consumer wastes. [18]

On 5 October 2010, biogas was injected into the UK gas grid for the first time. Sewage from over 30,000 Oxford shire homes is sent to Didcot sewage treatment works, where it is treated in an anaerobic digester to produce biogas, which is then cleaned to provide gas for approximately 200 homes. [19]

In 2015 the Green-Energy company Ecotricity [20] announced their plans to build three grid-injecting digesters.

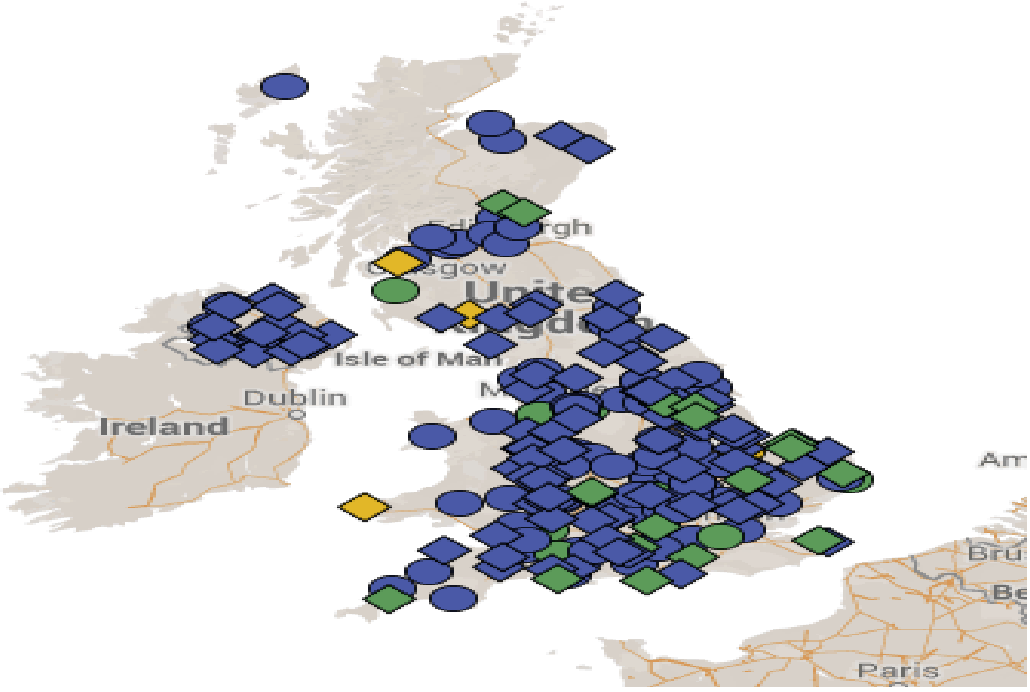


Figure 12: Biogas plant map of United Kingdom [21]

3.2.2.3 Austria

294 biogas plants were producing green electricity in Austria in 2008. The average size of 260 kWe installed power shows the decentralized structure of biogas. The feedstock is available in close proximity to the plants (manure, maize, grass) and transportation costs are kept to a minimum. The produced biogas is combusted in a gas engine which generates electricity and heat. Only plants also using the heat (excluding the heat used for the fermentation process) are permitted to feed-in electricity into the grid with favorable conditions, leading to better overall efficiency. [17]

This year two large bio methane plants were connected to the grid in Austria. The amount of biogas fed into the grid was 52% higher than last year.

Association of Gas and District Heating Supply Companies (FGW) points out that contrary to electricity generation, there are no incentives to connect biogas plants to the natural gas grid, but rather numerous obstacles imposed by gas and heat distributors. In Austria biogas is becoming an important source of energy generation with over 300 plants that produce 550 GWh annually which can cover the demand of 16,000 homes.

Michael Mock, the director of FGW and spokesman of Gas Initiative explains the rapid development of the sector: in 2013 a total of 55 GWh worth of bio methane were produced, during the first 4 months of 2014 already 35 GWh were produced, a 52% increase.

Bio methane is treated as normal gas, while electricity produced from biogas has a special environmental tariff. According to Mock, a reform is needed if Austria is serious about reducing its particle and $CO2$ emissions

Before being injected into the gas grid, biogas (50% to 75% methane) has to be upgrades to at least 98%. The first upgrading plant was built in 2005 and currently there are nine feeding seven million cubic meters of bio methane in the grid. According to FGW, there is potential to produce up to seven hundred million cubic meters of bio methane.

Two new big plants

In Lustenau, 18,600 t of waste are turned into 50 million kWh every year. No energy crops are used, only organic waste from the region of Voralberg, and the energy powers 300 homes. „This is energy from the region and for the region“, explains the engineer Johann Böckle of Vorarlberger Energienetze GmbH.

There is potential to power 3,000 homes is Voralberg. Besides, the additional price a year per household is only of 80 to a 100 additional euros a year. According to Mr. Böckle, this is a difference that the people of Voralberg to are ready to pay for clean energy and energy security. [22]

Figure 13: ElectraTherm Power+ Generator Installed at Biogas Plant in Austria

Profile of ElectraTherm Power+ Generator Installed at Biogas Plant in Austria

Biogas/Heat-to-Power Application on a GE Jenbacher 312

Location:	Inning, Austria
Gross Power Output Range:	18 – 32kWe
Thermal Heat Input Range:	260 – 450kWt
Hot Water Input Range:	180°F (82°C) – 200°F (93°C)
Hot Water Flow Range:	50 -130 GPM (3.15 – 8.21 l/s)
Year Commissioned:	2012

ElectraTherm installed its first Power+ in Austria at a biogas power generation facility to produce additional electricity from engine heat without additional fuel or emissions. The system produces biogas through anaerobic digestion to fire a 500kWe GE Jenbacher 312, generating electricity to sell to the grid and heat crops during harvest. With the inclusion of the Power+, excess engine heat will now be employed to generate additional electricity. This is the first application to our knowledge where an Organic Rankine Cycle (ORC) is incorporated into a biogas facility to supplement this impressive and efficient use of renewable energy. [23]

Figure 14: Biogas plant of Austria [16]

3.2.2.4 Sweden

Biogas from the sewage treatment plant has been upgraded since 1992 with a PSA-plant (Pressure Swing Adsorption) of an upgrading capacity of 200 Nm^3/h. This plant was built to upgrade biogas from the sludge digesters at the adjacent sewage treatment plant. A new upgrading plant (pressurized water wash) with a capacity of 660 Nm3 /h was erected in parallel with the co-digestion plant and was taken into operation in 1997. A third pressurized water wash plant was built in 2002 (capacity: 1,400 Nm^3/h) in order to cope with the increasing market demand for fuel. The biogas upgrading plants are located at the same site as the co-digestion plant.

Figure 15: Sweden's - and one of the worlds - first plants for production of liquefied biogas (LBG) in the town of Lidköping, southern Sweden. [25]

The upgraded gas from the upgrading plant is piped to the bus filling station and two quick filling stations in a low pressure PE pipeline. The upgraded biogas is compressed to 250 bar at the filling stations before it is filled into the vehicles. The gas production from the upgrading plants is approximately 5 million Nm3 /year, which corresponds to 5.5 million liter diesel.

Table 6: Linköping biogas plant – energy statistics (2004)

Total biogas production	48,000 MWh/year
Biogas delivered to vehicles	45,000 MWh/year

The upgraded biogas is used both in buses, trucks and in light duty vehicles (private cars, taxis and distribution vehicles). Svensk Biogas owns and operates 12 public refueling stations in Linköping and in the surrounding area. The filling stations are used by private cars as well as by taxis and distribution vehicles from different companies. The world's first biogas train had headed down the track between Linköping and Västervik on the east coast of Sweden in June 2005. The train is converted from diesel to bio methane propulsion by changing the engine and equipping the train with storage cylinders for compressed biogas. [24]

Figure 16: "Biogaståget Amanda" ("The Biogas Train Amanda") train near Linköpingstation, Sweden [26]

The market for biogas as vehicle fuels has been growing rapidly in recent years in Sweden. 2008 there were 17.000 vehicles driving on upgraded biogas/ natural gas. There are currently 38 upgrading plants and in 2008 about 25% of Sweden's biogas production was used as vehicle fuel and 60 % of the total gas volume sold as vehicle fuel was biogas and only 40 % consisted of natural gas. 10 The awareness of the advantages of biogas is increasing, such that the demand for biogas as a vehicle fuel is greater than the supply in some regions, such as the Stockholm area. New technologies for the purification and transport of biogas have been developed and the number of filling stations for biogas in Sweden amounts to more than 120 and the number are continuously increasing. [17]

3.3 Developing World

Under this section I attempt to take review of developing countries like China, India, Nigeria, Ethiopia etc. These countries have a great acceleration in the biogas sector.

3.3.1 China

China is one of countries in the world to have used biogas technology early in its history. By the end of the nineteenth century, simple biogas digesters had appeared in the coastal areas of southern China. Mr. Luo Guorui invented and built an eight cubic meter Guorui biogas tank in 1920, and established the Santou Guorui Biogas Lamp Company. [33]

But the Chinese had experiment the applications of biogas widely since 1958. Around 1970, China had installed 6,000,000 digesters in an effort to make agriculture more efficient. During the last years the technology has met high growth rates. This seems to be the earliest developments in generating biogas from agricultural waste.

In 1996, grain production reached 504.3 million tonnes in China. It was hard to sell the grains. Nanyang in Henan Province had 6.7 million ha of wheat crop (1 percent of wheat cropland in China), and a record yield of 9.5 tonnes/ha that year. Nanyang also had 1.5 million tons of shop worn grains. So, Tianguan Alcohol Factory expanded its operation to consume 1.75 million tons of shop worn grains/year to produce denatured alcohol as fuel for automobiles, and used the dregs of the distiller to produce biogas in a 30 000 m3 digester, supplying more than 20 000 households or 20 percent of the population. Nanyang became a biogas city in China.

Meili village of Shaoxing Country, Zhejiang Province produces 28 000 pigs, 10 000 ducks, 1 million ducklings and 100 000 chickens each year. In 2001, they spent 1.2 million Yuan to build digesters to treat 30 tons of livestock and poultry wastes and nightsoil. This produced enough biogas for more than 300 households plus 7 200 tons of organic fertilizer each year.

Hongzhi Alcohol Corporation Limited located in Mianzhu in Sichuan Province is the largest alcohol factory in south-western China, and produces alcohol for human consumption. It runs a service using industrial organic wastewater, sewage and dregs to produce biogas, paid for by industry and residents in cities, but provided free to farmers. The company also built a biogas power plant generating 7 million kilowatts per hour.

The city of Mianzhu treats 98 percent of municipal sewage including wastewater from hospitals through digesters with a total capacity of 10 000 m3. The treated water reached national discharge standards, greatly improving the environment.

Up to the end of 2005, China has 17 million digesters with annual production of 6.5 billion m^3 biogas, mostly in rural areas, with 50 million people enjoying the benefits of biogas technology. The annual production of biogas is projected to reach 25 billion m^3 by 2020. Biogas could provide energy to one quarter of households in rural areas.

Biogas is at the Centre of a burgeoning eco-economy in China. As animal husbandry goes intensive, there are many large or medium size livestock and poultry farms in the suburbs of cities. An example is Fushan farm in Hangzhou, with 32.47 ha paddy fields, 4 ha tea trees, 13.7 ha water shields and 7.3 ha fishponds. It also produces 30 000 laying hens, 150 000 broilers, and 8 000 pigs a year, with 15 tons of solid waste and 70 tons of wastewater discharged daily, a huge amount of pollution. But using biogas digesters to deal with the pig and poultry wastes, biogas energy becomes available for processing tea and heating the chicken coop, and there’s fodder for fish and pigs and fertilizers for tea trees and the paddy fields, and no pollution is exported to surrounding areas. This eco-farm has now moved to the outskirts far from the city because of its malodor, however. It is possible to use a combination of multiple micro-organisms to deodorize pig manure or chicken manure. Also, the large amounts of water in slurry could be reused to wash away wastes in hog houses as a water-saving measure.

Northern China has cold winters but sufficient sunshine. Digesters do not operate below 10 C, and pigs raised in winter eat but do not fatten. People also lack fresh vegetables in winter. All these problems are solved with a four-in-one eco-model that provides a greenhouse to plant vegetables, a shed to raise pigs, a digester underneath the pig shed and a toilet in the big green house adjoining the pig shed. The pigs grow well with manure flowing into the digester together with human excreta. The digester works well because the temperature could be kept above 10 C, and it greatly improves the living conditions of farmers. The digester provides biogas as energy, slurry and dregs as fertilizers, and the pigs produce carbon dioxide to enrich the greenhouse to produce plenty of quality vegetables.

In southern China, a five-in-one model incorporates pigs, digester, fruit orchard, light trap, and fishponds. The pig manure flows into a digester to be fermented. Biogas is harvested to provide energy for cooking and lighting. The digested slurry is used as fertilizer for the fruit gardens and feed for pig and fish. The light-trap hangs above the fishpond to attract and kill pests, which become additional fish-feed. This model is practiced especially in Guangxi Province in southern China, where a yellow sticky board (a kind of fly paper) is hung in the orchard for additional pest control. [33]

In the 1990s China’s biogas strategy was extended to remote communities in west Guangxi, where wood for fuel was in short supply and rural electricity was not available. In 2002 the strategy was a key component of a six-year IFAD-funded project to improve and sustain the livelihoods of poor rural people while rebuilding and conserving natural resources.

Most of the farmers who live in Guangxi province don't earn enough to pay for fuel or electricity, and few are connected to the power grid. Women, who generally have the responsibility of collecting fuelwood, spent hours every day collecting wood and then spent more time cooking in their smoke-filled homes.

"We used to cook with wood," says Liu Chun Xian, a farmer involved in the project. "The smoke made my eyes tear and burn and I always coughed. The children too were often sick and had to go to the clinic, which was expensive. Now that we're cooking with biogas, things are much better." In addition to producing energy, the project has resulted in better sanitary conditions in the home.

The poorest households, which had only one pig, built small units that could produce enough gas to provide lighting in the evening. Households with two or more pigs built larger units that could produce gas for cooking as well as for lighting.

The double bonus of energy and compost motivated poor people to adopt this technology in significant numbers. By 2006, the project had exceeded its target by providing more than 22,600 biogas tanks and helping almost 30,000 households in more than 3,100 villages. As a result, 56,600 tons of firewood can be saved in the project area every year, which is equivalent to the recovery of 7,470 hectares of forest.

"Farmers used to spend a lot of time collecting wood," says Lu Gui Hong, the mayor of Fada, a village included in the project area. "As you can imagine, it wasted a lot of time. Since we constructed the biogas digesters, farmers have a lot of time to find other ways of earning money. For example, in my village we now grow tobacco and organic tea."

In the last five years, with more time to spend improving crops, farmers in Fada have increased tea production from 400 kilograms to 2,500 kilograms a day. Average income in the village has quadrupled to just over US$1 per day. This is significant in a country where the poverty line is 26 US cents per day.

The Guangxi project has become a catalyst for other initiatives in the region. To date, 2.73 million biogas tanks have been built in villages, benefiting about 34.2 per cent of the rural households in Guangxi. It is estimated that 7.65 million tons of standard coal and 13.40 million tons of firewood are saved annually in Guangxi because of the use of biogas. [34]

On the other hand china has a gigantic business of readymade portable biogas plant in local and international market.

Figure 17: Portable biogas plant [35]

Some of the portable plant can be fold or can keep in very small place and can easily use.

3.3.2 India

Biogas in India has been traditionally based on dairy manure as feed stock and these "gobar" gas plants have been in operation for a long period of time, especially in rural India. In the last 2-3 decades, research organizations with a focus on rural energy security have enhanced the design of the systems resulting in newer efficient low cost designs such as Deenabandhu model.

In India, the estimate for the production of biogas is about 20,757 lakh cubic meters in 2014-15. This is equivalent to 6.6 core domestic LPG cylinders. This is equivalent to 5% of the total LPG consumption in the country today. Within states, Maharashtra tops the production with 3578 lakh cubic meters while Andhra Pradesh comes next with 2165 lakh cubic meters.

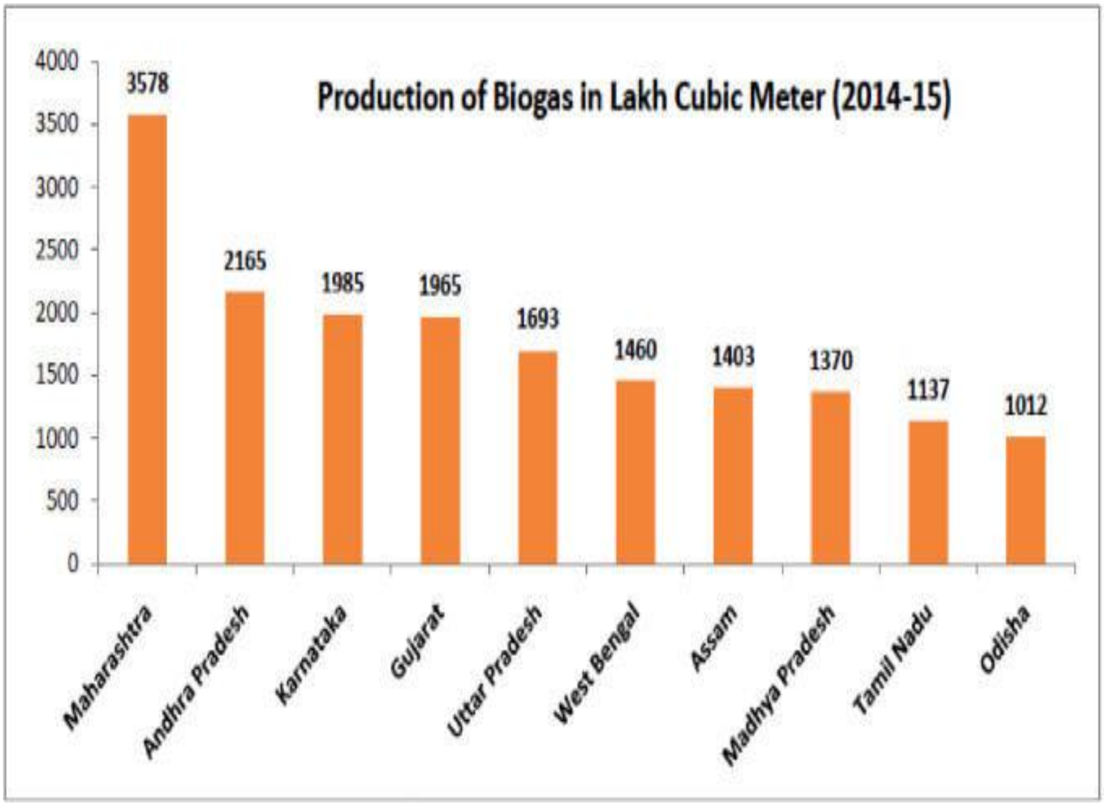


Figure 18: Production of biogas in India [36]

Within states, Maharashtra tops the production with 3578 lakh cubic meters while Andhra Pradesh comes next with 2165 lakh cubic meters.

Apart from these, under the twelfth five year plan (2012-2017), the government of India had set a target to set up 6.5 lakh biogas plants across the nation with a budget of Rs.650 core under a program called, the National Biogas and Manure Management Program (NBMMP). It had been estimated that by setting up of these biogas plants, about 1-6 cubic meter of biogas per day and 4745 lakh cubic meter biogas could be produced annually. The program is being implemented by the State Nodal Departments/State Nodal Agencies and Khadi and Village Industries Commission (KVIC), Biogas Development and Training Centers (BDTCs).

The NBMMP is being implemented as a central sector scheme. It provides for setting up of family type biogas plants mainly for rural and semi-urban households. The scheme provides for capital subsidy, turn-key job fee for supervision of installation and free maintenance warrantee for five years, organization of training courses, workshops/seminars and information dissemination. The

Capital subsidy provision of Rs.1500/- per plant for fixed dome Deenbandhu type and floating gasholder KVIC type brick masonry models.

Free maintenance warrantee up to five years.

Out of the 1.06 lakh biogas plants planned to be setup in 2013-14, 79% that is, 83540 plants have been successfully setup. For the year 2014-15, of the 1.1 lakh plants planned to be setup, 45146 were already setup as of 31st December 2014. Comparing both the years, there is a 1.7% increase in the number of plants that were planned to be setup and also an encouraging 3% increase in the number installed until the end of 2014.

Central subsidy is being extended for setting up of a biogas plant. For one cubic meter biogas plant, subsidies of Rs.5500 and Rs.7000 are given for general category and SC/ST respectively whereas for setting up a 2-6 cubic meter biogas plant, Rs.9000 and Rs.11000 subsidies are given to the general and SC/ST categories respectively.

North-Eastern states, including Sikkim are given a higher subsidy in setting up biogas plants. In this region, Rs.15000 and Rs.17000 are given for one cubic meter and 2-6 cubic meter biogas plants respectively. However, in Assam, these numbers are a little lower. There is also an additional subsidy of Rs.1200 given for toilet linked biogas plants. The following table captures the amount of subsidy extended for setting up of a biogas plant. [36]

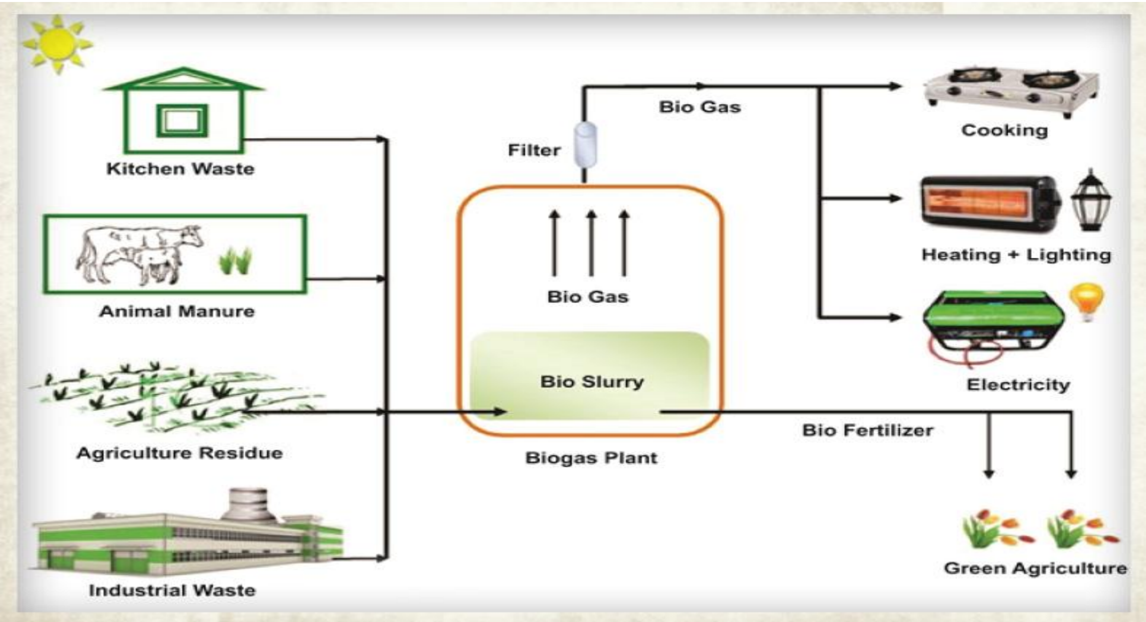


Figure 19: Biogas-production in India [37]

Biogas based power units can be a reliable decentralized power generation option in the country. In order to promote this route of power generation, specifically in the small capacity range (3 kW to 250 kW), based on the availability of large quantity of animal wastes and wastes from forestry, rural based industries (agro/food processing), kitchen wastes, etc.; a number of projects of different capacities and applications will be taken up for refining the technical know-how, developing manpower and necessary infrastructure, establishing a proper arrangement of operation & maintenance and large scale dissemination. The projects to be taken up by any village level organization, institution, private entrepreneurs etc. in rural areas as well as areas covered under the Remote Village Electrification (RVE) program of MNRE other than the industries and commercial establishments covered under Urban, Industrial & Commercial Applications (UICA) programs for sale of electricity to individual/ community on mutually agreeable terms. The implementing organizations must ensure that sufficient feed stock/ materials for proposed biogas plants size are available on sustainable basis and the beneficiary organization gives an undertaking that the plant would be maintained and operated for a minimum period of ten years. [38]

The increasing industrialization, urbanization and changes in the pattern of life, which accompany the process of economic growth, give rise to generation of increasing quantities of wastes leading to increased threats to the environment. In recent years, technologies have been developed that not only help in generating substantial quantity of decentralized energy but also in reducing the quantity of waste for its safe disposal.

The Ministry is promoting all the Technology Options available for setting up projects for recovery of energy from urban wastes. In developed countries, environmental concerns rather than energy recovery is the prime motivator for waste-to-energy facilities, which help in treating and disposing of wastes. Energy in the form of biogas, heat or power is seen as a bonus, which improves the viability of such projects. While incineration and biomethanation are the most common technologies, pyrolysis and gasification are also emerging as preferred options. A common feature in most developed countries is that the entire waste management system is being handled as a profitable venture by private industry or non-government organizations with tipping fee for treatment of waste being one of the major revenue streams. The major Advantages for adopting technologies for recovery of energy from urban wastes are to reduce the quantity of waste and net reduction in environmental pollution, besides generation of substantial quantity of energy. [39]

Figure 20: Small biogas plant in garden [40]

Status of Proposals received during the year 2014-15 under Biogas Power (off-grid) Programme

Sl. No.	State	Implementing Agency	No. of proposals received	Proposed capacity of biogas plant (m^3)	Proposed power generation capacity (kW)	Total CFA including administrative charges (Rs in Cr.)	Date of receipt	Status
1	Karnataka	BDTC, Bangalore	14	4700	472	1.83	17.01.2014	Sanctioned (F. No. -25-32/2012-BE 09.06.2014)
2	Uttar Pradesh	UPNEDA, Lucknow	16	1630	216	0.83	16.07.2014	Sanctioned (F. No. - 25-1/2014-15/BP 10.09.2014)
3	Punjab	PEDA, Chandigarh	22	3535	343	1.44	01.09.2014	Sanctioned (F. No.-25-5/14-15-BE 05.11.2014)
4	Andhra Pradesh and Telengana	NREDCAP, Hyderabad	7	855	90	0.39	30.08.2014	Sanctioned (F. No. - 25-4/14-15/BPP 03.11.2014)
5	Madhya Pradesh	MPUVN, Bhopal	1	85	10	0.04	24.09.2014	Sanctioned(F.No.25-7/2014-15/BPP(23/12/2014)
6	Andhra Pradesh and Telengana	NREDCAP, Hyderabad	2	1560	187	0.58	08.10.2014	Under process* (File with IFD)
7	Uttar Pradesh	UPNEDA, Lucknow	10	1155	134	0.57	10.09.2014 & 17.11.2014	Sanctioned(F. No. 25-6/2014-15/BPP) 30/12/2014
8	Punjab	BDTC, PAU, Ludhiana	1	200	24	0.09	18.11.2014	Under process* (File with IFD)
9	Nagaland	DNRE, Nagaland, Kohima	1	85	3	0.01	12.09.2014	Incomplete documents * (Letter issued on 28.11.2014)
10	Maharashtra	MEDA, Pune	6	1550	186	0.70	23.10.2014 & 28.10.2014	Incomplete documents* (Letter issued on 28.11.2014)
11	Tamil Nadu	TEDA, Chennai	12	4800	480	1.80	11.11.2014	Transferred to U&I division on 21.11.2014 for further n.a. at their end
12	Delhi	IIT Delhi	1	170	20	8.80	08.12.2014	Transferred to U&I division on 11.12.2014 for further n.a. at their end
13	Delhi	IIT Delhi	1	400	48	15.80	08.12.2014	Incomplete documents* (Letter issued on 12.12.2014)
	Total		**94**	**20725**	**2213**	**32.88**		

* Proposals could not be processed as limit of sanction (150% of BE) was exhausted, which was further enhanced (i.e. 200% of BE) vide letter no. 1/6/2013-P&C dated 24.11.2014 by the Competent Authority.

Courtesy [41]

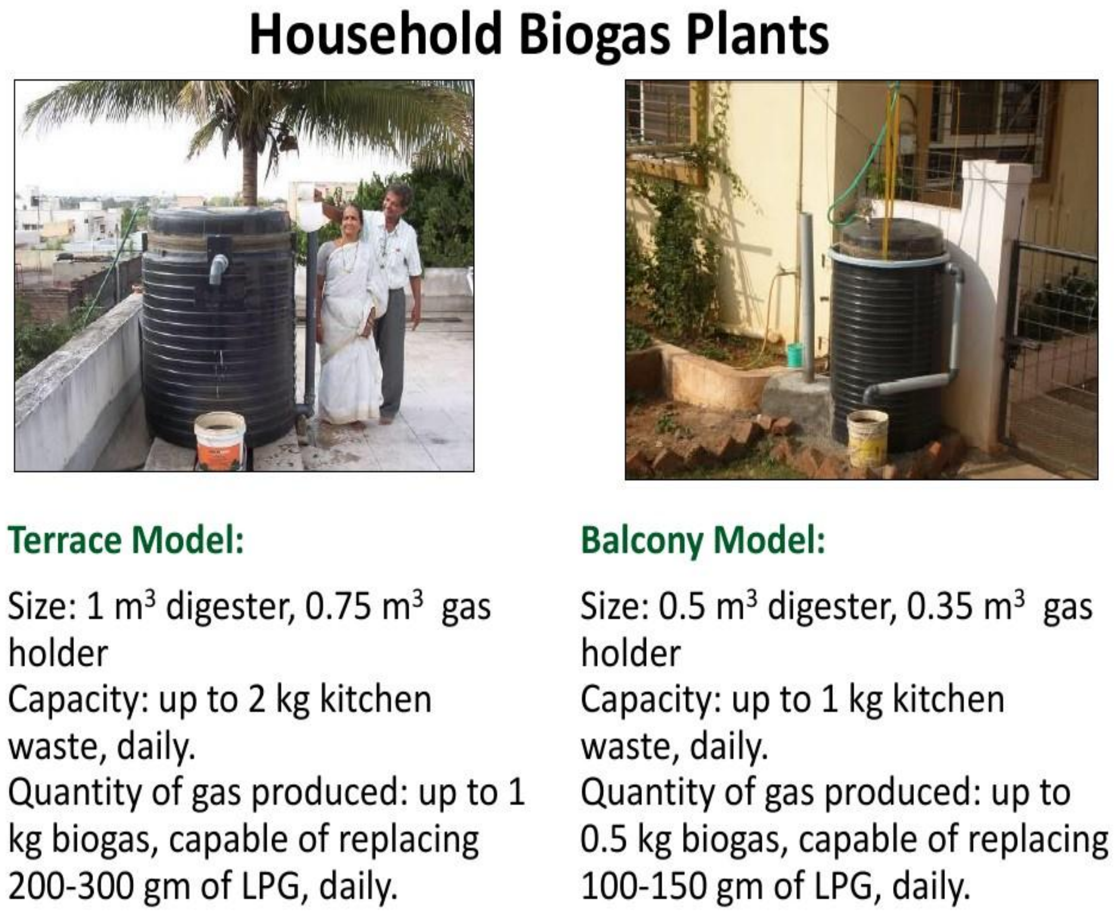


Figure 21: Household small biogas plant [42]

During the initial stages, the Government may provide the funds to meet the operational losses, so that the technology may be absorbed by the rural masses. Intensive efforts are made to upgrade technology, to produce more gas without excessive sophistication.

To save commercial energy, prevent deforestation, reduce soil erosion and preserve organic biomass for recycling, and to produce more food grain, a comprehensive program for the use of non-conventional energy was introduced by the Government of India. Special emphasis was laid on the biogas program. In the first phase, stress was laid on the family size biogas plants, but later emphasis was shifted to the installation of community/institutional biogas plants to provide cheap and smoke- free cooking gas to the rural populace who cannot install their own plants, due to poverty, lack of dung and land for installation of the digester. The DNES, Government of India, provided a 10% subsidy for the installation of community biogas plants. There were 20 community biogas plants in operation and several more under construction in the State of Punjab in 1988. In India there were over 250 community/ institutional biogas plants in operation. Production of biogas during the winter, costly dung collection arrangements, inadequate slurry handling systems and lack of outside financial help are some of the constraints in the promotion of the program. [43]

3.3.3 Nigeria

Even though Nigeria is an oil and gas producer, the country faces a severe energy crisis because of continuous supply disruptions. Nigeria's centralized oil and gas distribution networks are easy targets for rebels, energy hackers and criminals alike. But a Nigerian Sweden-based biotechnologist, Dr. Ade Abdulrahim, says that his native country has a resource that can provide a much safer, because decentralized flow of energy. The technology is simple, easy to manage, highly efficient, renewable and economic and can be located independently of supply lines (contrary to natural gas thermal stations). The resource would take away urban pollution and waste streams, a major problem in Nigeria's rapidly growing cities. We are of course talking about biogas. According to the scientist, Nigeria could generate as much as 600,000MW of it merely by using the existing organic waste streams (and not dedicated biomass crops). This potential comes down to roughly 4740 gigawatt hours of electricity, enough to meet the current electricity needs of around 58 million Nigerians (Nigeria's per capita electricity consumption stands at around 81 kWh per year / compare to the U.S. average at 13,000). The expert, who was one amongst the many Nigerians who attended the just-concluded Diaspora Forum on Science and Technology [*.doc] in Abuja, said he was confident that the Nigerian Federal Government could exploit this potential by investing a mere US$2bn into the technology. [44]

Figure 22: Bio waste landfill in Nigeria like Dhaka [45]

The fluctuating nature of oil price on the world market and the increasing awareness of the impact of fossil fuel combustion on our environment are some of the reasons given by (Akinbami et al. 2000). Over a half of Nigeria’s population of approximately 124 million is rural and two-thirds of the energy consumption of the country is mainly fuel wood in the form of charcoal (Akinbami et al. 2001). The high demand for fuel wood is due to petroleum shortages both in the urban and rural areas. With an estimated population growth of 2.8%, this has meant that the demand for fuel wood is ever rising against a fixed supply thus creating a deficit. As at 1992 Nigeria accounted for 62% of total fuel wood production and consumption in the whole of West Africa (Akinbami et al.2001). Could there be another reason behind Nigeria's interest in biogas apart from energy, considering that the domestic digesters are seldom able to meet the basic cooking needs of the users. Studies have shown that a whopping 1.77 million tons of solid waste is generated annually in the country and biogas technology has been marked as a promising way to tackle the waste. Using biogas technology to produce gas is not in the pipeline however there are few pilot projects for research into waste management (Akinbami et al. 2001).

The challenges that have been encountered in Nigeria during their biogas dissemination programs are very similar to those faced elsewhere in China, India and Ethiopia: issues with high cost of the digester, support services to maintain the digesters and peoples difficulty to embrace the technology.

As usual, the initial cost of acquiring the digester is a major stumbling block as the rural folk and the intended users are often too poor to come up with the lump sum. The ownership of the digester then comes into play. When the digesters are funded through aid, the users fail to take proper care of it which may be because of they feel no sense of ownership.

Issues relating to maintenance of the digesters also come into play. During the wet season, maintaining an internal temperature higher than 15 degree Celsius inside the digester becomes a hurdle yet it is a very important condition that must be satisfied if the digester is to function properly. In the future, research and development will have to be geared towards customizing biogas technology to suit local Nigerian conditions.

Figure 23: Small Biogas plant in Nigeria [46]

Figure 24: Biogas plant in Nigeria [47]

In this period of epileptic and erratic power supplies that are hampering business development in the country, the biotechnologist said that establishing biogas-driven power plants could prove a better and more efficient alternative to other sources of power generation. [44]

3.3.4 Ethiopia

Ethiopia is a mountainous country in the Horn of Africa with over 45 percent of the land more than 1 500 meters above sea level. That is where the majority of the population, particularly smallholder farmers, lives. They practice mixed farming, combining arable crops with livestock.

Livestock play a pivotal role in smallholder farming, providing draught power for ploughing fields, dung for fertilizing the soil and for cooking alongside fuel wood. Livestock also provide a cash reserve by supplying meat and milk to the urban population. However, due to poorly managed grazing, deforestation, and climate change, farmers are facing land degradation from the loss of soil and nutrient depletion. To make things worse, families live with indoor air pollution cooking with dung and biomass on inefficient fires, and water pollution from poor or non-existent sanitation. These factors severely undermine the health and productive capacity of the farming households, particularly women and children.

The NBPE is a project developed by the Ethiopian Government and SNV (The Netherlands Development Organization) with the support of HIVOS, a Dutch international development funding organization; its coordination office is in the Ministry of Water and Energy. The project aims to help 14 000 Ethiopian smallholder farming families install and manage anaerobic digester plants, to provide them with an alternative, renewable, clean, and safe energy (biogas, 60 % methane) for cooking and lighting, as well as a readily available organic fertilizer (bio slurry) to improve crop yields. Households are also encouraged to attach a toilet to the biogas digester to improve sanitation.

The NBPE is working in the four main crop growing regions of the country: Amhara, Oromiya, Southern Nations, Nationalities and Peoples (SNNP), and Tigray Regional States. The first biogas digester plants were built in 2009. By the end of August 2011, 1 634 biogas digesters were installed and working.

In the latter part of 2009, the Institute for Sustainable Development (ISD) based in Addis Ababa was invited to be a partner in the NBPE with special responsibilities for the effective and efficient use of the 'bio slurry' residue of biogas production. ISD has pioneered the use of compost with smallholder farmers in Ethiopia, and understands ecological organic agriculture well. [48]

In Ethiopia, the average cultivated area per household is 0.96 ha and the average yield of cereals is below 2 000 kg/ha. Food security is thus an over-riding concern for nearly 40 percent of smallholder farming families. Use of chemical fertilizers is very low; consequently there is an opportunity for good quality organic fertilizers to help farmers increase their productivity.

ISD has developed a method to record crop yields from farmers' fields. [49] When the crop is mature, the farmer and his/her development agent harvest three one-meter squares from a field. The crop is threshed (the process of loosening the edible part of the grain from the chaff), the grain and straw is weighed, and then returned to the farmer with the development agent recording the yield data, the farmer's name, the crop and the input used. The straw is important because this is the main source of animal feed during the long dry season. Samples of the same crop are taken from good, average, and poorer fields. The inputs are bio slurry compost, no input (check) and chemical fertilizer (mostly urea) if the farmer so chooses.

The 2010 cropping season provided the first opportunity to find out if the use of bio slurry compost could improve crop yields in both grain and straw.

The response to bio slurry compost application was large: the average yield of wheat grain increased by 64 %, while that of barley grain increased by 72 % over check. Even the farmers with poorer fields benefitted from the use of bio slurry. For wheat, the average yield for a poor field more than doubled from 1170 to 2450 kg/ha, while that for barley increased from 1150 to 2270 kg/ha.

In the village of Waza, farmers growing barley had included the use of chemical fertilizer in their treatments. The results are presented in Figure.

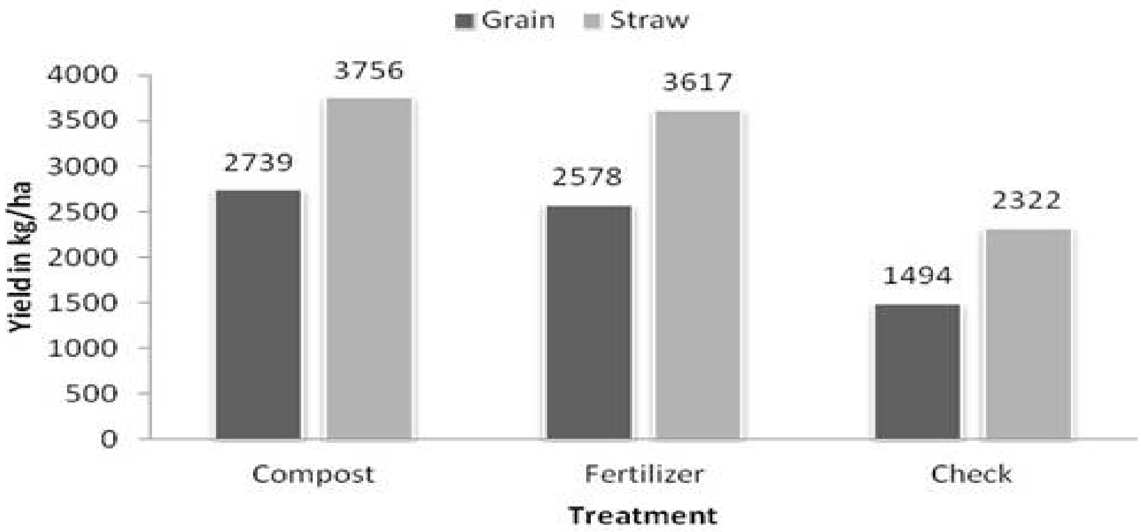


Figure 25: Yields of barley from bio slurry compost, chemical fertilizer and no input (check) in Waza, Hintalo Wejerat, 2010

As can be seen, bio slurry compost or chemical fertilizer almost doubled the yield of grain compare to check. Furthermore, the use of bio slurry was as effective, or slightly more so than chemical fertilizers. The impact on straw yield was smaller, indicating that improving the supply of nutrients to the crop resulted in a higher increase in the production of grain.

In Ofla, the bio slurry development agents focused on collecting crop yield data from farmers growing wheat. In Mankere, six farmers who had used all three treatments, compost, chemical fertilizer and check cooperated with the development agent who took data from a total of 541 m2 plots. The average grain yields were 4 500 kg/ha from the use of bio slurry, 4 600 kg/ha from chemical fertilizer and 3 600 kg/ha from check. In Hashengi, farmers were using an improved wheat variety, HAR 1685. The average grain yields were 4600 kg/ha from both the check and bio slurry, and 5300 kg/ha from the use of chemical fertilizer.

These data show that applying bio slurry and using chemical fertilizer both increase yields, significantly in Hintalo Wejerat. Chemical fertilizer only gave a higher yield where the farmers were using an improved variety of wheat that probably responded specifically to chemical input.

In September 2010, the government launched a five-year Growth and Transformation Plan (GTP). Agriculture is the major source of economic growth, while particular focus is given to empowering women and youth and ensuring their benefits. The making and use of organic fertilizers, particularly compost, is incorporated as part of the agricultural extension package. The importance of compost in sequestering carbon in the soil is recognized as one of the means to mitigate and adapt to the challenge of climate change.

The NBPE has the potential to contribute significantly to the target set for the use of compost and to improve food security by 2015 in Ethiopia.

Biogas plants provide an alternative form of safer, cleaner energy to homes as well as organic compost to farms. The first data from field studies are showing improvements in crop yields equivalent in most cases, to chemical fertilizers. [50]

Figure 26: Portable biogas carrier is carried easily [51]

Figure 27: Portable biogas plants are installed in village [52]

Hence it is easily noticeable that Ethiopia takes the biogas to the people with huge advantages such as portability, easy to install, alternative energy, helpful for farming, smoke free cooking etc.

3.4 Comparative analysis

Based upon the literature review, analysis can be done with some experience of biogas in different countries. The biogas produced is mainly used for generation of heat and electricity in most countries with exceptions for Sweden and Switzerland where approximately half of the produced biogas is used as vehicle fuel. Many countries, such as Denmark, Germany and South Korea, among others, show initiatives and interest in increasing the share of the biogas to be used as a vehicle fuel in the near future.

Here summary of the some countries reports that are present the condition of biogas production and use at those countries.

The biogas production is presented for the following plant types:

- Waste water treatment plants
- Biowaste – co-digestion or monodigestion of food waste and other types of biowaste
- Agriculture – digestion at farms (mainly manure and energy crops)
- Industrial – digestion of waste stream from various industries (e.g. food industries).
- Landfill – landfills with collection of the landfill gas

3.4.1 Austria

To meet the European Union 20-20-20 goals, Austria has to increase the amount of renewable energy to 34 % of total energy consumption. The Energy Strategy Austria envisages biogas to contribute to these targets by delivering electricity or biofuel.

Production of biogas

Today the main production of biogas is derived from energy crops, sewage sludge and landfills. The annual biogas production corresponds to 1.5–2.5 TWh.

Table 7: Status of biogas production in Austria (values from 2012)

Plant type	Number of plants with electricity generation	Energy production (GWh/year)*
Waste water treatment plants and landfills	45	31
Agriculture and biowaste	291	554
Total	336	585

* = Produced energy as electricity excluding efficiency losses.
Source: Ökostrombericht 2013, Energie-Control Austria

Utilization of biogas

In Austria biogas is utilized mainly for electricity and heat production. Even though the aim is to upgrade more biogas to biomethane for use as a vehicle fuel, this change is taking place rather slowly.

Table 8: Utilization of biogas in Austria (values from 2013)

Utilization type	GWh
Electricity	564
Heat	640
Vehicle fuel	7 *
Flare	13 *

* = installed capacity
Source: Ökostrombericht 2013; Franz Kirchmayr (Arge Kompost & Biogas)

Financial support systems

Support is provided for electricity production via the Green Electricity Law (Ökostromgesetz 2012).

Feed-in tariffs for 2013 are:

0.1950 EUR/kWh up to 250 kWe,

0.1693 EUR/kWh from 250 - 500 kWe,

0.1334 EUR/kWh from 500 - 750 kWe,

0.1293EUR/kWh for higher than 750 kWe,

+ 0.02 EUR/kWh if biogas is upgraded

+ 0.02 EUR/kWh if heat is used efficiently

It is required that a minimum of 30% manure is used as a substrate to get the feed-in tariff. If organic wastes are used, the feed-in tariff is reduced by 20%.

3.4.2 France

The view of the French Environment and Energy Management Agency is to produce 70 TWh biogas in 2030 and that 600 biogas plants will be built every year. 50% of the produced biogas shall be injected into the grid, 30% shall be used to produce electricity and the remaining 20% shall be used to produce heat. In 2050, the aim is to produce 100 TWh.

Production of biogas

In France it exits 256 biogas plants and 245 landfills. Only 90 of the 245 landfills are valorizing the biogas. The number of farm AD plants is expected to double by the end of 2013.

Table 9: Utilization of biogas in Austria (values from 2013)

Plant type	Number of plants	Electricity production (GWh/year)	Heat production (GWh/year)
Sewage sludge	60	97	540
Biowaste from MSW	11	51	15
Industrial	80	7	350
On-farm and centralized plant	105(90+15)	260 (120+140)	390 (190+200)[1]
Landfills with biogas valorize	80	858	296
Total	336	1273	1591

[1] heat recovery = 210 GWh/year (90 GWh/year on farm + 120 GWh/year centralized plants)
[2] source ADEME : ITOM, les installations de traitement des ordures ménagères en France – Résultats 2010,octobre 2012

Utilization of biogas

In France there is a strong development of on-farm and centralized biogas plants and for landfills to recover biogas in electricity production (today 90 out of 245 landfills). Around 120 on-farms AD plants are built until 2013 and near 15 centralized units. In addition, 60 WWT and 80 agrofood industries AD plants are operating right now.

In 2010, a study showed a relatively low energy recovery from biogas, around 60% of raw energy, the main partcoming from landfills (Market study on anaerobic digestion and biogas valorization in France, Ernst & Young,May 2010).

Regarding the table, 44% of the energy recovery is transformed in electricity and 56% in heat.

Financial support systems

In France there is a feed-in-tariff system for electricity produced from biogas with the following properties (energy efficiency bonus and manure bonus included, tariffs revised yearly, values of 2013):

0.8580 to 0.14521 EUR/kWhe for landfills

0.1182 to 0.2110 EUR/kWhe for AD plants

It also exist upgrading tariffs with the following properties:

45 to 95 EUR/MWh for biomethane from landfills (depending of volume, values of 2011)

69 to 125 EUR/MWh for upgrading the biogas to biomethane from AD plants (depending of volume and thenature of the feedstock, values of 2011)

3.4.3 Germany

The Federal Government of Germany has decided to redirect the energy policy and considers renewable energy as a cornerstone of the future energy supply. By 2020 the share of renewable energy in terms of electricity and total energy demand should be increased to 35 % and 18% respectively.

Production of biogas

Within Europe most biogas plants have been built in Germany. The vast numbers are agricultural plants, but also biogas plants digest sewage sludge, bio-waste, industrial wastes and waste from landfills. The main substrates used for biogas production in the agriculture sector are a mixture of energy crops, e.g. maize silage, and animal manure.

Table 10: Status of biogas production in Germany from different plants 2012

Plant type	Number of plants	Energy production* (GWh/year)
Sewage sludge	1400	3100
Biowaste	95	4500
Agriculture	7800	29400
Industrial	250	3420
Landfills	400	550
Total	9945	40970

* = Produced energy as electricity, heat, vehicle fuel or flared excluding efficiency losses.

The technical potential for biogas production in Germany until 2020 amounts to 116 TWh/year.

Utilization of biogas

In 2012 the biogas was used for electricity (26.7 TWh), heat (14.0 TWh) and vehicle fuel (0.35 TWh). This means that 4.4 % of electricity, 1% of heat and 0.1% of vehicle fuel total consumption is produced from biogas.

Table 11: Utilization of biogas in Germany, data from BMU, AGEE Stat

Utilization type	GWh	%
Electricity	26650	65
Heat	14000	34
Vehicle fuel	350	1
Flare	n.d.	n.d.
Total	41000	100

According to data of the German Energy Agency (DENA) and German Biomass research centre (DBFZ) biogas upgrading capacity is growing rapidly. By 2020 it is planned to have 1000-1400 upgrading plants, most of them with capacities in the range 500-800 Nm^3/h.

Financial support systems

The revised financial support for renewable energy in 2012, the "Amendment of the Renewable Energy Sources Act (EEG)" is shown in the table, the feed-in tariff depends on plant size, type of substrate and the biogas upgrading.

Table 12: Amendment of the Renewable Energy Sources Act (EEG) 2012 in Germany

Plant size	Basic bonus (EUR/kWh)	Substrate category I[1)] (EUR/kWh)	Substrate category II[2)] (EUR/kWh)	Bonus OFMSW[4)] (EUR/kWh)	Upgrading bonus (EUR/kWh)
< 75 kWe	0.25[3)]				0.030 until 700 Nm^3/h
< 150 kWe	0.143	0.060	0.080	0.160	
< 500 kWe	0.123	0.060	0.080	0.160	0.020 until 1000 Nm^3/h
< 750 kWe	0.110	0.050	0.080	0.140	
< 5 MWe	0.110	0.040	0.080	0.140	0.010 until 1400 Nm^3/h
< 20 MWe	0.060	0	0	0.140	

[1)] Biogas crops, e.g. maize, beets, whole plant silage, > 60 wt% animal slurry

[2)] Plants from landscape conservation, clover, > 60 wt% animal waste,

[3)] > 80% animal slurry (wt%)

[4)] Organic Fraction of Municipal Solid Waste

3.4.4 Sweden

In Sweden there is a governmental aim to produce 50 percent of the energy from renewables by 2020 (this has already been reached), but there are no specific targets for the biogas production. A committee inquiry recently reported its findings after 1.5 years of work on how fossil free transportation can be reached in 2050. The results are expected to be important for the future governmental support for biomethane production in Sweden.

Production of biogas

In Sweden the production of biogas has been fairly constant at around 1.3–1.5 TWh for several years. The main reason is the difficulties in showing a feasible profit for new investments and new biogas plants. The biogas production of new plants is balanced by the steady decline in landfill gas production. Table shows the Swedish biogas production from different types of plants.

Table 13: Biogas production in Sweden from different plants (values from 2012).

Plant type	Number of plants	Biogas production* (GWh/year)
Sewage sludge	135	660
Biowaste	21	507
Agriculture	26	47
Industrial	5	121
Landfills	55	254
Sum	242	1 589

* = produced raw biogas expressed as its energy content from the different plant types
Source = Produktion och användning av biogas år 2012, Statens Energimyndighet 2013

Utilization of biogas

In Sweden, around 50% of the biogas is used as vehicle gas. This part is increasing every year to meet the increasing demand from the increasing number of gas vehicles. The main part of the remaining biogas is used for heat production. The entire utilization of biogas in Sweden is summarized in Table below.

Table 14: Utilization of biogas in Sweden (values from 2012)

Utilization type	GWh	%
Electricity	41	3%
Heat*	524	33%
Vehicle fuel	845	53%
Flare	165	10%
Total	1575	99%

* = including heat losses, e.g. during electricity production, and heat used by the biogas plan

Source = Produktion och användning av biogas år 2012, Statens Energimyndighet 2013

In Sweden, nearly all upgraded biogas is used as automotive fuel, designated "fordonsgas" (vehicle gas), which means that the annual biomethane production in Sweden is around 845 GWh, according to Table.

Financial support systems

Sweden has no feed-in tariffs, but instead use other support systems, mainly focused on increasing the usage of biomethane as automotive fuel. The existing support systems are:

- No carbon dioxide or energy tax on biogas. Today this correspond to a value of 68 EUR/MWh compared to petrol and 52 EUR/MWh compared to diesel of which 26 EUR/MWh is from the carbon dioxide exemption and the remaining part is from the energy tax exemption.
- 40% reduction of the fringe benefit taxation for the use of company NGVs until 2016
- Investment grants for marketing of new technologies and new solutions for biogas during 2013–2016.Maximum 45% or 25 MSEK (~3 MEUR) of investment cost
- A joint electricity certificate market in Norway and Sweden. The producer gets one certificate for every MWh electricity produced from renewable resources and end-users are obliged to buy certificates in relation to their total use. Average 2012 price was approximately 17–22 EUR/MWh
- 0.2 SEK/kWh (~0.02 EUR/ kWh) for manure based biogas production to reduce methane emissions from manure. Total budget 240 MSEK (10 years).

3.4.5 United Kingdom

The UK government is still supporting the role out of AD in England and devolved administrations.

- In England, Defra set out in 2011a vision for AD to generate between 3-5 TWh of heat and electricity by 2020.
- Wales as part of their 'One Wales Delivery Plan' have created a capital and revenue financial support package for local authorities who wish to adopt AD technology.
- In April, Scotland will see the introduction of food waste bans to landfill. This has driven up the AD capacity and this trend is expected to continue.
- Northern Ireland with its attractive government subsides (4 ROCs) for AD has seen an increase of farm fed (grass) facilities. Number of plants is 9

Production of biogas

There are today 66 AD plants treating food waste (74 MWe capacities) and 53 farm plants (29 MWe capacities). The number of new plants has increased rapidly since 2005, along with gas production and is predicted to keep on rising rapidly.The electrical generation from AD in United Kingdom has increased by 52% during the period 2009–2012.

Table 15: Status of biogas production in United Kingdom (number of plants from 2013, energy generation from

Substrate/Plant type	Number of plants	Energy Generation* (GWh/year)
Sewage sludge	146	720
Biowaste (co-digestion)	66	523**
Agriculture	53	4098
Landfills	345	5154
Total	610	10494

* = Produced energy as electricity and/or heat

**= including both Biowaste and Industrial plants

The upward trend is expected to continue to 2030. The estimated total energy generated by AD biogas in 2030 could be around 23 to 37 TWh (Analysis of Characteristics and Growth Assumptions Regarding AD Biogas) [53]

Utilization of biogas

The main use for biogas in the UK today is for electricity production (103 MWe from AD alone). There is increasing interest in upgrading biogas to biomethane and in using biomethane as a vehicle fuel. Currently less than five biogas upgrading plants are in operation, but several more are planned and some are being constructed.

Examples of upgrading biogas to vehicle fuel have been demonstrated in the UK although the market is still very much in its infancy. DECC statistics have reported that 1.1 million litres of fuel was produced from biogas in the financial year 2012–2013, but this accounts for only 0.002% of total fuel produced from renewable sources in the UK. There are currently only around 5 CNG filling stations in the UK.

Financial support systems

Feed-in tariffs for electricity generation from August 2011 are, 0.14 GBP/kWh (~€ 0.17) for up to 250kW, 0.13 GBP/kWh (~€ 0.16) for >251 kW up to 500kW and 0.09 GBP/kWh (~€ 0.11) for >500kW. Double Renewable Obligation Certificates (ROCS) apply to AD, although in Northern Ireland, quadruple ROCS are awarded to plants with sizes up to 500 kW and triple ROCS are awarded to plants in the range >500 kW to 5 MW.

A new renewable heat incentive operating from April 2011 provides a tariff of 0.068 GBP/kWh (~€0.08) for biomethane injected into the natural gas grid and combusted downstream. Renewable Transport Fuel Obligation Certificates were worth 0.1115 GBP/litre (~€0.13) in late2010.

WRAP recently released its Annual Survey of the Organics Recycling Industry report which covers the market size in 2012. Headline figures of 7.54 million ton of organic waste input into composting and AD in 2012 with 2.51 million ton of mixed waste input to MBT facilities. The following table breaks down the headline figures by region.

Table 16: WRAP recently released its Annual Survey of the Organics Recycling Industry report

	England	Northern Ireland	Scotland	Wales	UK Total
Compost (inc IVC)	5 080 000	140 000	430 000	190 000	5 850 000
AD (Commercial,R&D and on-farm)	1 280 000	10 000	120 000	10 000	1 430 000
AD (Inudstrial)	250 000	0	0	10 000	260 000

Source [(54)]

Figure 28: Evergreen Gas' small scale biogas upgrading to vehicle fuel facility

Biogas production in the IEA Bioenergy Task 37 member countries is clearly dominated by Germany with more than 9000 biogas plants. No other member country today has more than 1000 biogas plants and only UK has more than 500 plants except for Germany, according to the available data. Around 0.5-2 TWh of biogas is produced annually in most countries except for UK and Germany where the production is several times larger. In UK 10 TWh of energy (mainly electricity) was produced from the biogas during 2012 and in Germany the amount of energy generated was 40 TWh (mainly electricity).

Financial support systems are very different from country to country. Various systems with feed-in tariffs, investment grants and tax exemptions exist. A clear correlation between the financial support system and the way biogas is utilized can be seen in the Task 37 member countries. In UK and Germany with feed-in tariffs for electricity have led to that most of the biogas is used to produce electricity, while the system with tax exemption in Sweden favors the utilization of the biogas as a vehicle fuel. [55]

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Chapter Four

Data Presentation and Analysis

4.1 Introduction

This chapter attempts to present and analyze the data that was collected during the fieldwork and literature study. In this chapter presents the data in that try to understand how and why the various people decided to use biogas. Then also look at who are the main users of biogas and the people who and why do not use biogas in Bangladesh. Finally how we can influence the people of Bangladesh in the use of biogas as compared to the people from other countries.

As I know the huge advantage of biogas as a student of renewable energy technology I could not understand the poor condition of biogas in Bangladesh having all facilities that need to grow this sector. Before going to the field I set few questions to exactly know the experience of people of Bangladesh with Bangladesh. The questions table is given below

Table 17: Survey question Pattern Table

For those who use biogas	For those who do not use biogas
Why they use biogas (try to find out advantages)	Is there any other kind of renewable energy use by them?
What kind of problem they face (try to find out disadvantages)	Why the do not use biogas (try to find out the problem why biogas is not popular)
In future have they any wish to use biogas for long term	In future have they any wish to use biogas

4.2 History of biogas in Bangladesh

The first biogas plant in Bangladesh was constructed in 1972 at the premises of Bangladesh Agriculture University (BAU) following Indian KVIC floating-drum model. During 1972 - 1980, a total of 72 such plants were constructed with technical assistance from IFRD.

In the 80s, efforts were undertaken by EPCD (150 floating-drum and 110 Chinese fixed dome plant), BCSIR, DANIDA (few trench and bag type digesters), LGED (over 200 plants), DLS (about 70 plants) and Grameen Bank (17 plastic bag digesters). In 1992, IFRD and Dhaka City Corporation jointly built an 85 m3 bio-digester at Dholpur using city wastes. Several other pilot schemes were undertaken by LGED during 1992 -1994 using city wastes, human excreta, water hyacinth and poultry dropping. A wider dissemination of biogas took place while BCSIR implemented the "Biogas Pilot Plant Project" during 1995-2000 (1st phase) and 2000-2004 (2nd phase). During this period, 21,858 fixed dome plants were constructed throughout the country. During 1998-2003, LGED also implemented a parallel biogas project constructing 1,120 domestic plants. Recently, Infrastructure Development Company Limited (IDCOL), a government owned energy and infrastructure financing company, with the support from Netherlands Development Organization (SNV) started 'National Domestic Biogas and Manure Programme' under which 36,450 domestic size biogas plants with capacity ranging 1.2 – 4.8 m3 gas production are planned to be constructed by end of 2009. Moreover, GTZ has created a facility to support construction and financing of biogas digesters with capacity of above 4.8 m3, installed mostly in commercial dairy, poultry and slaughterhouse. In addition, Ministry of Youth and Sports has an ongoing biogas program in ten selected areas of Bangladesh.

4.3 Provider of biogas technology in Bangladesh

Bangladesh is one of the low energy consuming countries of the world. The national grid could so far cover only 35 per cent of the total population, and only 3 per cent people are enjoying piped gas supply. About 97 per cent people of Bangladesh live in rural areas, where the situation is worse. As a result, rural to urban migration is high in Bangladesh. In the rural areas, the houses are scattered. Neither grid nor piped supply is suitable for those areas. Decentralized supply systems like solar, biogas; wind, etc. have no alternative. About 90 per cent of the electricity now produced in the country is based on natural gas, which has limited reserves and will be exhausted in the near future. [1] With zeal and commitment to serve the nation, LGED has been involved in dissemination of biogas technology since 1985 and has been able to demonstrate its usefulness at more than thousand sites in different parts of the country. The full meaning of LGED is "Local Government Engineering Department". This is a government motivated village development organization working for development of village people.

Other important institution is IDCOL (Infrastructure Development Company Limited) which has made an arrangement with German KFW and Dutch SNV to set up more biogas plants across the country, said Bangladesh has now an estimated 50,000 biogas plants, much of which had gone dysfunctional at the beginning. But the plants that have been set up later have shown an efficiency of 85 percent.

In initial survey of IDCOL show that biogas plants could be set up among two million rural households and meet their long demand for clean energy for domestic uses-cooking and lighting. But aspects like lack of proper motivation, appropriate technology, rising cost for plants as well as availability of cow-dung and poultry excreta have been barring the sector to flourish at mass scale. IDCOL's Director S M Formanul Islam said the biogas plants could be a great solution for those rural households, who want to cook food by clean energy sources and reduce indoor pollutions. He said a biogas plant now costs over Taka 35,000, but the costs could be recovered in three years.

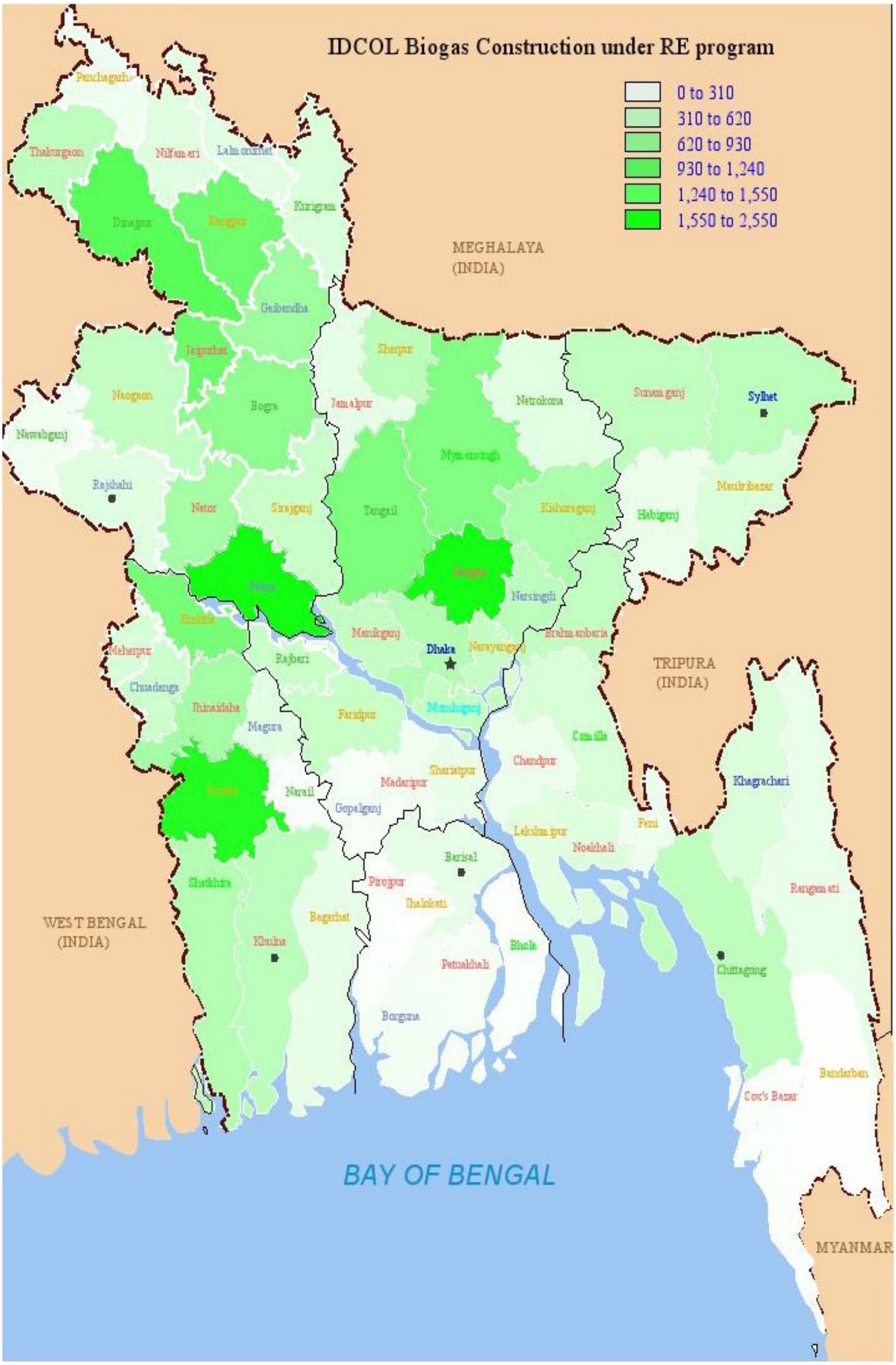

Figure 29: Biogas Map of Bangladesh [2]

The concept of biogas has been pioneered by Bangladesh Center for Science and Industrial Research (BCSIR) in early eighties and they set up bulk of the biogas plants across Bangladesh. But much of the plants could not sustain due to lack of proper supervision and maintenance. A new initiative has been taken to popularize the system through technical and cash incentives.

Table 18: Biogas plants installed so far in Bangladesh

Organization	No. of Biogas plants
Bangladesh Council of Scientific & Industrial Research (BCSIR)	58100
Infrastructure Development Company Ltd (IDCOL)	2142
Local Government Engineering Department (LGED)	46900
Department of Environment	260
Bangladesh Rural Advancement Committee (BRAC)	2850
German Technical Cooperation (GTZ)	2270
Ministry of Youth and Sports	8100
Bangladesh Small & Cottage Industries Corporation	30
Bangladesh Agricultural Development Corporation	20
Danish International Development Agency (DANIDA)	4
Bangladesh Agricultural University	2
Housing & Building Research Institute	2
Bangladesh Academy for Rural Development (BARD)	1
Bangladesh Commission for Christian Development	1
Bangladesh Rice Research Institute	1
Department of Livestock	70

Promoters of renewable energy said, the country is expected to see a surge of biogas plants in next five years as initiatives have been taken to set up 150,000 such plants in rural households by 2016.

4.4 Biogas technology use in Bangladesh

There are many technologies available today to deal with the problem of excessive use of biomass for household energy consumption in rural areas of developing countries. These can include solar, wind, hydro power, tidal power etc. Many of these technologies are well suited in specific areas based on the natural resources available there. However, a common problem for the majority of these technologies are that they are often associated with very high initial capital costs and a dependency on foreign financing and expertise. One solution that has proven it to be very useful in most areas in Bangladesh is the use of biogas.

Biogas is produced when organic material is digested in an anaerobic environment. The organic materials, substrates, typically consist of kitchen waste, human excreta, cattle manure, waste water, agricultural residues etc. The most common biogas plants used in developing countries are small household based fixed dome models. They are cheap to build and can be constructed by using materials available locally. Household biogas plants commonly use kitchen, toilet waste (human excrete) and cattle manure.

Generally in Bangladesh there are three types of basic designs of biogas plants are used. They are given below

- Floating cover digester
- Fixed cover digester
- Plastic cover digester

Floating cover digester: It works on the principle of constant pressure, changing volume. The digester, cylindrical well, commonly made from brick and cement, is covered with a floating steel cylinder with an open bottom. As the cylinder has a constant weight, it moves up when gas production is higher than consumption and comes down under the reverse conditions.

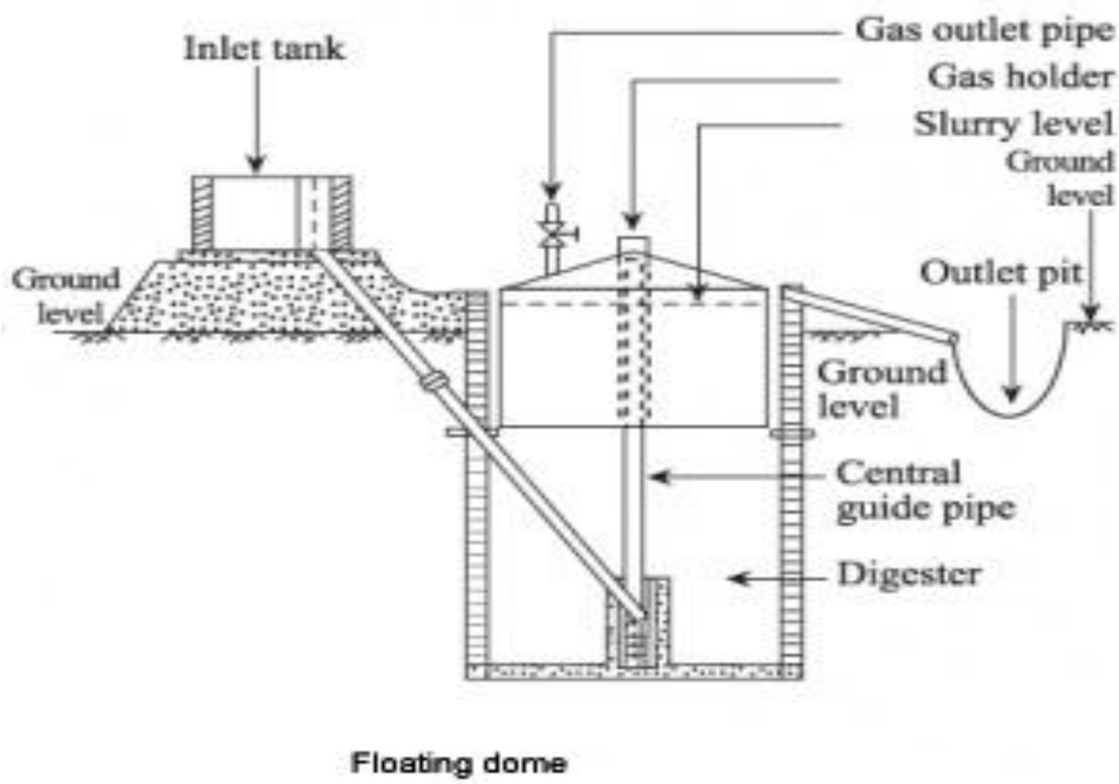

Figure 30: Floating cover digester [3]

Fixed cover digester: It works according to the principle, constant volume, changing pressure. When the rate of gas production is higher than that of gas consumption pressure inside the digester rises and expels some digester contents into the outlet compartment. When the consumption is higher than production, pressure inside the digester falls and the expelled materials in the outlet compartment run back to the digester

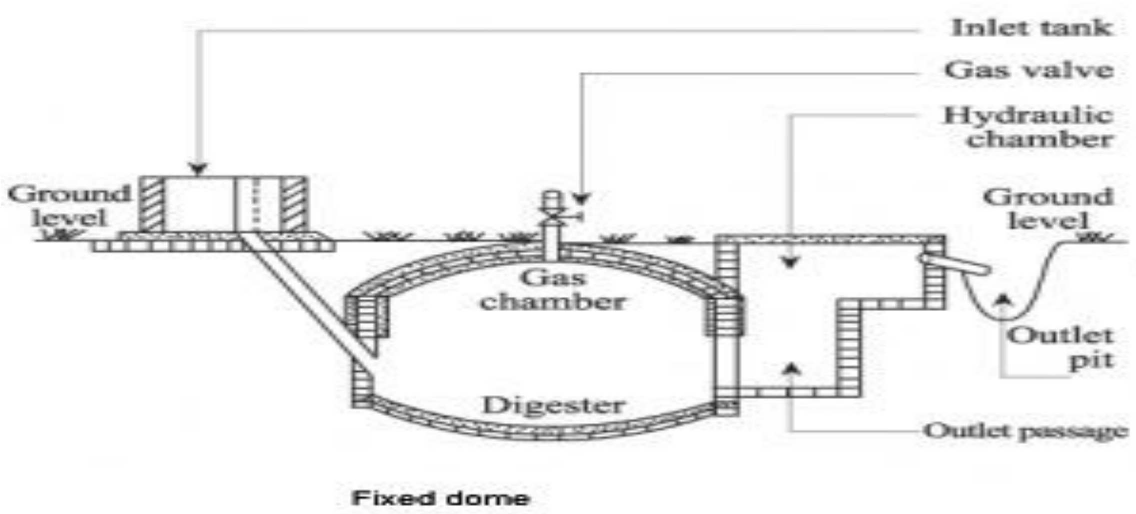

Figure 31: Fixed cover digester [3]

Plastic Cover digester: A long cylindrical polythene/PVC bag, half-buried longitudinally in the ground, is fed with fresh cow-dung slurry at one end and discharged at the other. With the formation of gas, the bag swells like a balloon and the gas is led out to the point of use through a pipe by putting pressure on the balloon form outside. It is use in rarely.

Biogas demonstration and research plant in Institute of Energy, University of Dhaka By team of Institute of Energy and Practical Action.

Table 19: Information of Biogas demonstration and research plant in IE

Installation year	2015
Capacity	1.2 m^3
Technology	Fixed Dome
Fermentation type	Wet
Raw materials	Cow dung, poultry litter, kitchen waste etc.

Figure 32: Biogas demonstration and research plant in IE

One of largest biogas plant in Bangladesh is situated Satkhira by Practical Action. It always produces gas. But it does not produce electricity always. To produce electricity biogas purification is required which is costly process.

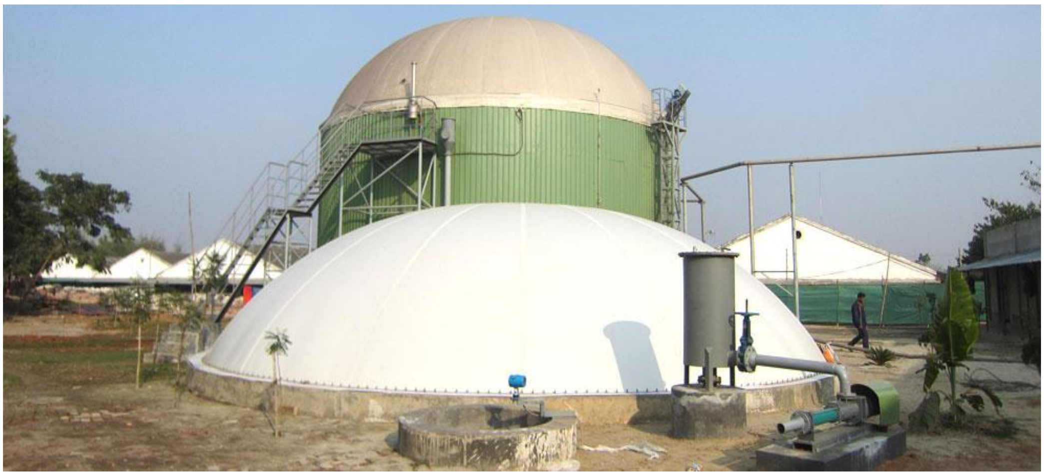

Figure 33: Biogas plant in Bangladesh

4.5 Current Costs of Domestic Biogas Plants

In Bangladesh, hardly any user buys a piece of land to set up biogas plant; rather it is assumed that biogas user already has a piece of land for biogas plant construction. Assuming this, cost of a biogas plant varies with changes in the following cost components. - Model or type of the biogas plant - Size and dimension of the biogas unit - Amount and prices of material - Labor input and wages At present, there are two major types of biogas plants constructed in Bangladesh. One is based on cow dung and the other on poultry droppings.

Table 20: Cost of Installation of Biogas Plant

Size of Plant (cft gas production per day)	Maximum Cost in BDT	Minimum Cost in BDT	Average Cost in BDT
100	15500	11800	13575
125	17600	12450	15750
150	23000	15200	18500
200	24000	15800	20100
250	28000	17000	23850
300	34500	30500	32500

4.6 Comparative analysis

Based upon the field study, analysis can be done with some experience of biogas in Bangladesh. Different respondents give different opinion about their experience with biogas. Some experiences are related with each other and some are not. But all the experiences are highly related with biogas energy scheme and important to increase the use of biogas in future.

Motivating factors and reason of Installation

The respondents were asked to give most important reasons motivating factors for the installation of biogas plants. As per them, the most popular motivating factors were the economic benefits including saving of time and money, environmental benefits, availability of subsidy and health benefits including the reduction in smoke-borne diseases. The following table shows the responses of the respondents on the reasons for the installation of biogas plants.

Table 21: Motivating factors to install biogas plant

Motivating factors	Percentage of user (%)
Economic benefits (saves time and energy)	47
Subsidy	23
Health benefits	82
Non-availability of other fuel sources	5
Environmental benefits (saving of forest, clean surrounding etc.)	41
Motivation from other plant owners	35
Proper use of cattle dung	17
Pressure from neighbors (in the case of poultry)	11
Use digester as septic tank	5
Fish feed	35
Adopt the new technology and make the village ideal living place	23
Motivation from service provider	29

Some respondents gave more than one reasons

It is encouraging to note that 23% users were adopt the biogas as new technology to make the village ideal living place and 35% users were motivated by other plant users to install biogas plants. This indicates the potential of existing plants to become tool for promotion and extension of the technology.

Training and Orientation to Users

In fact, the functioning of biogas plant is basically determined not only by the quality of construction and workmanship involved but also by the quality of operation and maintenance efforts from the users. The following table illustrates the responses of the users when being asked if they have received any training on operation and maintenance of biogas plants from the service providers.

Table 22: Training on operation & maintains of biogas plant

Type of training received	Percentage of user (%)
No training received	17
Training not provided but leaflet/booklet/manual provided	52
One day orientation training provided by service provider	41
Short term o & m training (7days or less)	29
Long term o & m training (more than 7 days)	11
On the spot instructions from mason/company supervisors etc.	23
Training provided by other NGO's (not the service provider)	17

Some respondents gave more than one reasons.

It is evident form table that there is high need of training to educate the users on basic operation and maintenance of the installed plants. Existing physical status and functioning of majority of the plants under study also suggested that the users were not fully aware of the importance of effective operational activities and timely repair works for trouble-free performance of biogas plants.

Husbandry

During the time of survey the biogas user owned about 86 cattle (cow, ox and buffalo) at an average of 5.06 cattle per user. Number of cattle has been differing from user to user. The following table shows the number of cattle owned by household during the time of survey and five years back.

Table 23: Number of cattle owned

No. of cattle	No. of family (5 years ago)	No. of family (during the time of survey)
0	1	0
1-3	3	3
4-5	5	5
More than 5	8	9
Total	17	17

The maximum number of cattle was 19 and the minimum was zero. One user did not keep any cattle. 12 of the 85 cattle were reported to be open-grazed and the remaining was stall-fed. The number of cattle has been increased in five years ago except decline in case of one user.

Time distribution

When asked if the users have felt any difference in time allocated for cattle care before and after the installation of biogas plants, majority of the respondents replied that they did not experienced any changes. According to the remaining respondents, more time was needed to care cattle because they are now forced to stall-feed the cattle to produce more dung to feed into the digester. Such added time ranged from 10 minutes to 80 minutes which is quite insignificant. The total time saving after the installation of biogas plants as responded by the users has been summarized in the following table.

Table 24: Time distribution after the installation of biogas plant

Activity	Average time saving/min/day	Average time required/min/day
Cooking of meal	15	
Collection of fuel	30	
Cleaning of cooking vessels	10	
Maintain kitchen	30	
Collection of water		20
Waste management process	15	
Caring of cattle		50
Cultivating land	80	
Plant feeding	80	30
For lighting	10	
Average time	190 minutes (3 hrs 10 mins)	100 minutes (1 hrs 40 mins)
Average time save	90 minutes (1 hrs 30 mins)	

Besides the above-mentioned ten activities related to biogas plant, users did not feel any difference in allocated time before and after the installation of biogas plants.

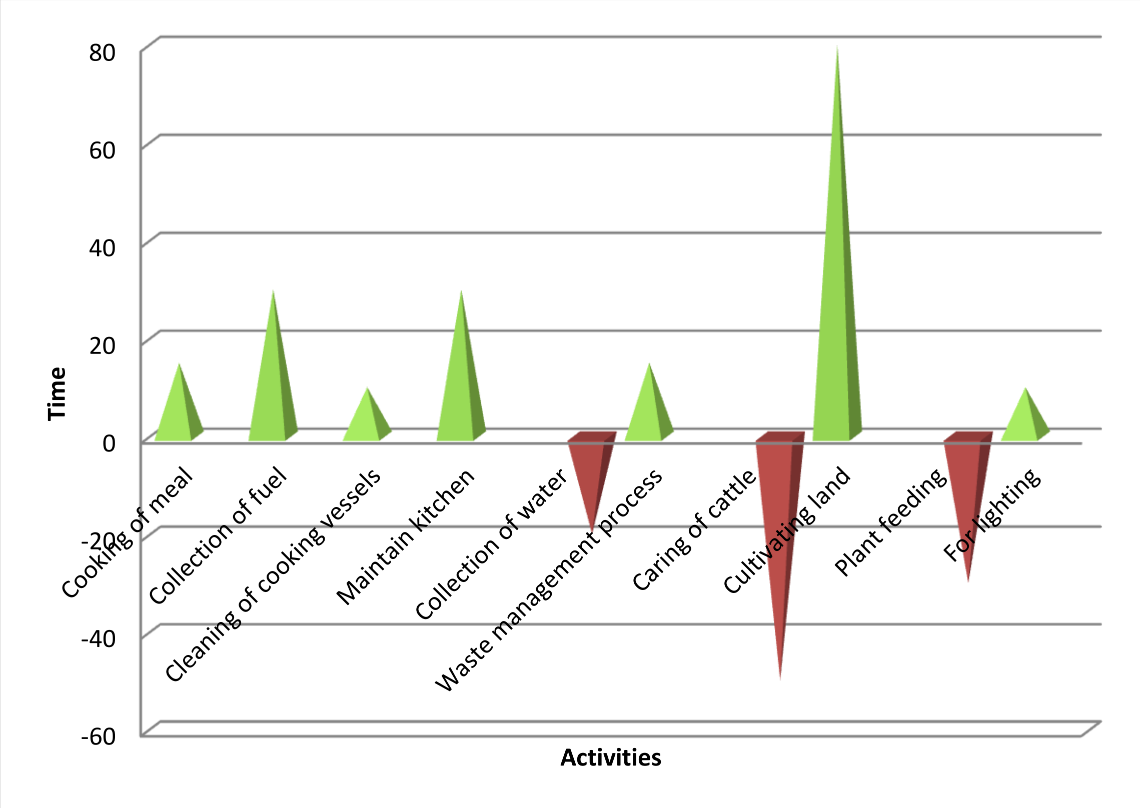

Figure 34: Time used for biogas related activities

Maintenance

Effective and timely management of routine repair and maintenance works are keys to the sustainability of biogas plants. As long as operational activities are carried out efficiently and routine maintenance works are carried out in time, biogas plants function properly. The following were the major repair works carried out as responded by the users:

Table 25: Major repairs works carried out

Repair works carried out	Positive responses (%)
Pipeline repaired	29
Main gas valve repaired/replaced	41
Gas stove repaired/replaced	5
Gas lamp repaired	35
Structures repaired/renovated	5

Some respondents gave more than one reasons.

The following table shows amount spent on repair works:

Table 26: Amount spent on repair works

Total amount spent in the last 12 months	Percentage of plants (%)	Total amount spent (BDT)
None (no expenditure)	17	0
Less than BDT 100	11	120
BDT 100 to 150	23	230
BDT 151 to 500	17	490
BDT 501 to 1000	11	1700
BDT 1001 to 3000	11	2400
More than 3000	5	3200
Total		8140

As shown in table a total of BDT 8140 was spent by the plant owners to repair their plants. Major share of this maintenance cost was reported to be taken by the gas stove followed by structural components. The average maintenance cost per plant was found to be BDT 478 per year.

Impact on Saving of Conventional Fuel Sources

Based upon the quantity of saving of conventional fuel sources, yearly monetary saving because of the use of biogas has been given in the following table

Table 27: Financial gain from saving of traditional fuel

Traditional fuel	Quantity use and saving (unit/year/family)			Average cost in BDT/unit	Total saving in BDT/family/year
	Before	After	Saving		
Firewood (kg)	3525	1138	2387	15	35805
Agricultural residues (kg)	1742	747	995	6	5970
Dried dung (kg)	1376	648	728	7.5	5460
Lpg (cylinder)	6.5	2.5	4	1250	5000
Natural gas (BDT)	0	0	0	900	0
				Total	52235

Average financial saving from biogas plant was calculated to be BDT 52235 per year/household, which a significant amount. The maximum saving was reported to be BDT 17090, whereas the minimum was BDT (-4750). The negative value indicates that the cost was increased. The increase in cost was reported to be the switching of fuel sources from firewood before the installation of biogas plant to biogas when the biogas plant was functional and again to LPG after the failure of biogas plant. The reason for switching to LPG was reported to be the reluctance of housewives to use firewood once they became habituated to cook in smoke free environment when they used biogas. The following table shows the financial saving in the biogas households under the study

Table 28: Financial saving in biogas households

Amount saved (in BDT)/month	Percentage of family (%)
More amount needed	5
Zero saving	11
Saving less than BDT 100	11
Saving BDT 101 to 500	17
Saving BDT 501 to 1000	23
Saving BDT 1001 to 3000	17
Saving more than 3000	11

This table clearly points out that 84% of the biogas households are experiencing financial benefit from biogas plants. Responses of 70% of the respondents mentioning that they experienced tangible financial benefit from biogas plants is encouraging in a situation that people often tend to overlook such gain because of the fact that biogas plants do not earn cash rather it only saves cash.

The responses of users on being asked if they have experienced any advantages of biogas over other traditional fuel sources have been summarized in the following table:

Table 29: Advantages of biogas over traditional fuel sources

Response	Percentage of respondents (%)
Comfortable and easy cooking	82
Time saving/fast to cook	52
Less costly	35
No ash and firewood in kitchen	70
Health friendly	23
Environment friendly (no smoke)	70
Less heat while cooking (temperature in kitchen is not increased)	41
Suitable in rainy season when firewood gets wet	47
No need of constant care during cooking (other works can be done while cooking)	17
More advanced and energy efficient	29
Anybody can cook/no need of constant blowing and less risk of burns	11

Some respondents gave more than one reasons.

This table indicated that the users considered comfortable cooking, smoke-free cooking environment, reduction in expenditure and time saving to be the most advantageous things of cooking in biogas

General condition of biogas plants

The outcome of the study indicated that despite number of defects and weaknesses, the functional status of biogas plants on an average was satisfactory. Among all the plants under analysis 67% plants were functioning satisfactorily, 28% plants were functioning partly and the remaining 5% plants were not functioning at all during the time of field investigation. The following pie-diagram illustrated the functional status of biogas plants under study:

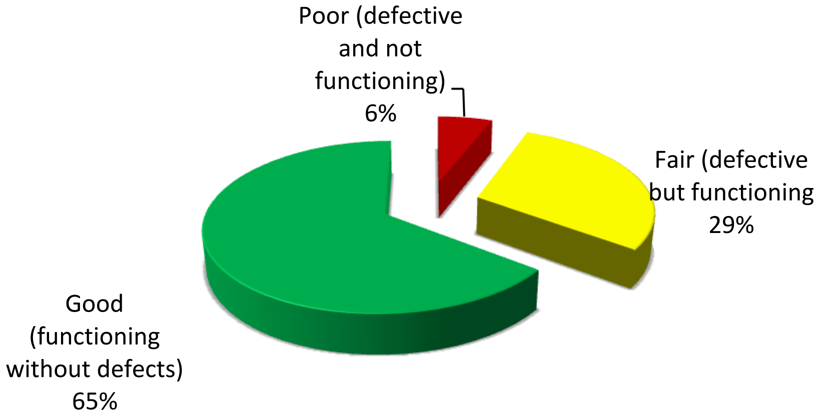

Figure 35: General condition of biogas plants

The reasons for non-functioning as reported by the respondents were

- Non-availability of feeding materials especially due to selling of cattle after the installation of biogas plant
- Poor workmanship during construction
- Sub-standard quality of construction materials and appliances
- Non-availability of repair and maintenance services
- Clogging of pipeline due to accumulation of condensed water
- Poor operational activities by the users

Some respondents whose plants do not function gave more than one reasons.

User's level of satisfaction

The respondents were encouraged to evaluate the performance of their plants by putting various direct and indirect questions. Their responses have been analyzed carefully to come to a conclusion on whether the respective users were satisfied with the output from and impacts of their plants on them. On being asked if they were satisfied with the functioning of their biogas plants, 53% responded that they were satisfied, 35%) responded that they were partly satisfied and the remaining 12% respondents responded that they were not satisfied. The following pie-diagram illustrated the user's level of satisfaction status of biogas plants under study:

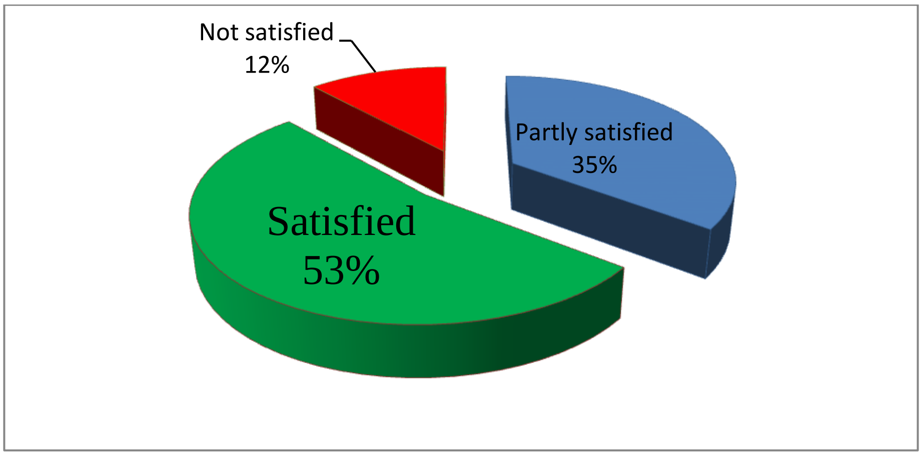

Figure 36: User's level of satisfaction

The reasons for full satisfaction were reported to be:

- Enough gas for cook/lighting
- Easy cooking/lighting
- Nutrient fertilizer
- Economic benefit
- Health benefits
- Environmental benefits
- Trouble free functioning of plant
- Workload reduction

The reasons for not satisfying were:

- No gas production from the plant
- Non-availability of feeding materials
- Poor quality of construction
- Not enough gas
- Often encounter technical problems
- Substandard quality of construction materials and appliances
- Non-availability of maintenance services

Interestingly, 50% users whose biogas plant was not functioning during the time of survey reported that they would like to adapt the technology again.

4.7 Experience of biogas in Bangladesh

All the data those got by asking different questions were studied and summarized. Here an attempt is taking to present people's experiences and opinions as classified data. Hither all the data has been classified as positive (daily life, health, economic, social etc.) and negative experience with biogas and have been shown in the following tables

Table 30: User's positive experience of biogas in daily life sector

Experience sector	Experience	Percentage of user (%)
Daily life	Smoke free cooking	82
	Short time cooking	52
	Cooking vessels cleaning process need small amount of time and it is comfortable.	47
	Cooking environment in kitchen is healthy	23
	No need to collect cooking fuel	70
	No need to worry about cooking fuel during rainy day	47
	No need to maintain extra storage place for cooking fuel	64
	Get rid of workload	76
	Safe to use	88
	Have opportunity of easy maintenance of daily work	41

Some respondents have more than one experience

Table 31: User's positive experience of biogas in health sector

Experience sector	Experience	Percentage of user (%)
Health	Free from the cooking in suffocating environment	76
	Released from diseases like cough and sneezes	35
	No need to blow air to stove from mouth	64
	Less risky than traditional stove or fireplace	64
	In winter in required situation easily use as fireplace or can heat room with smoke free environment	47
	Required less use of soap and detergent to clean cooking vessels	70
	In anaerobic digestion system harmful bacteria and parasites destroy and keep environment healthy	29
	As bio slurry can use in field hence required less chemical fertilizer	64
	Free waste management process	52
	Leads to improvement in the environment, and sanitation and hygiene	35
	Free from air pollution	29

Some respondents have more than one experience

Table 32: User's positive experience of biogas in economic sector

Experience sector	Experience	Percentage of user (%)
Economic	Save money because biogas replaces expensive firewood, charcoal and kerosene etc.	82
	As kitchen remain clean and tidy hence required less effort maintain kitchen	47
	No need to pay extra money for lighting	35
	No need to pay extra money to heat room in required condition	5
	Reduce the cost of waste management	52
	As bio slurry replaces chemical fertilizers hence save money	64
	Using bio slurry instead of chemical fertilizer can produce more crops	52
	Using bio slurry can reduce attack of differ diseases in corn field	35
	Required less doctor and medicine fee due to live in healthy environment	35
	Efficient way of energy conversion	29
	The technology is cheaper and much simpler than those for other bio-fuels	11
	Save time and money to collect cooking fuel	82
	Development of cattle and poultry is encourage hence increase income source	41

Some respondents have more than one experience.

Table 33: User's positive experience of biogas in social sector

Experience sector	Experience	Percentage of user (%)
Social	Due less workload people can visits one another home	76
	Due less expenditure they can save money hence increase social status	64
	No need to collect cooking fuel so children can play at that time	35
	Environmental advantage	29
	Required less wood hence no need to cut down tree	23
	Improve sanitation condition	35
	Reduce use chemical fertilizer in agricultural	64
	Provide fetor free environment	47

Some respondents have more than one experience.

Some roundabout but important experiences

Biogas has some roundabout but important experiences which cannot understand in short time or in small scale. Hence people cannot directly admit these experiences during interview or discussion. But some of them observe these experiences. Experiences are

Table 34: User's positive experience of biogas in different sector

Experience sector	Experience	Percentage of user (%)
Different	Create job opportunities	41
	Reduce co_2 emissions	5
	Reduce higher level of deforestation	5
	Reduce land filling by adding value to residues	11
	Protect from raise sea water level	0
	Improve habitat for native wildlife and improve biodiversity	0
	Protect from global warming	0
	Protect from acid rain	0
	Reduce net greenhouse gas emissions	0

Some respondents have more than one experience.

The respondents rated easy and comfortable cooking, environment friendly technology, time saving and workload reduction, nutrient rich fertilizer, economic benefits, fetor free environment, released from diseases like cough and sneezes and health improvement as positive experiences.

The users also mention no need to blow air to stove from mouth, less risky than traditional stove or fireplace, in winter in required situation easily use as fireplace or can heat room with smoke free environment, required less use of soap and detergent to clean cooking vessels, in anaerobic digestion system harmful bacteria and parasites destroy and keep environment healthy, as bio slurry can use in field hence required less chemical fertilizer, free waste management process, leads to improvement in the environment, and sanitation and hygiene, free from air pollution as positive experience.

User cannot obtain some experiences with biogas in such as create job opportunities, reduce CO_2 emissions, protect from raise sea water level, reduce higher level of deforestation, improve habitat for native wildlife and improve biodiversity, reduce land filling by adding value to residues, improve habitat for native wildlife and improve biodiversity, protect from global warming, protect from acid rain, reduce net greenhouse gas emissions etc.

After all the positive experiences obtain by the users of Bangladesh is different from other countries like UK, USA, Germany, India, China etc.

As everything has disadvantage with its advantage. Sometime these disadvantages occur due to mismanagement or misuse of the system. Some disadvantages are unavoidable or slightly decrease able. Biogas has no major disadvantage as other traditional system have. But user of biogas experience from this hazard usually. The negative experiences are

Table 35: User's negative experience of biogas in different sector

Experience sector	Experience	Percentage of user (%)
Different	High initial cost	64
	Problem with plant waste management	29
	Sometime spread fetor	47
	Required some technological knowledge hence make it complicate to operate	70
	Sometime hard to collect required waste for plant	5
	Hazards to human health in transporting some kind of waste for plant	23
	Low efficiency and hard to increase	17
	Sometime help to grow mosquito and house fly	41
	During rainy season required extra care to keep the plant dry	23
	During winter season if temperature fluctuation cause problem of gas production	11
	Required servicing when pipes get blocked which is costly	35
	Biogas contains some gases as impurities which is not good for health	11
	Social limitation and psychological prejudice against the use of raw materials	82

Some respondents have more than one experience.

Bio slurry produces as by product of biogas some time create big problem in urban area. Because generally it has no use in urban area and its management system become costly and awful.

The negative experiences of biogas are not actually disadvantage. These are consequences of ignorance. Because maximum of these can be overcome or reduce if we follow some precautions. By taking necessary steps we can also reduce or remove these negative experiences. Hence it is better to call these negative experiences as challenges with biogas.

Suggestions given by respondents

The respondents were encouraged to give suggestions for the effective implementation of future biogas program in the country based upon their experience with biogas technology. The responses received from them presented in the table given below:

Table 36: List of respondent's suggestions

Suggestions	Percentage of user (%)
Increase subsidy to benefit the poorer section of communities	47
Reduce the cost of installation	82
Install plants according to family size	35
Make arrangements to store biogas in cylinder	47
Make arrangements to portable and ready biogas plant	52
Improve construction quality and workmanship	58
Avail credit facilities for the potential users	23
Improve the quality of biogas stove	29
Produce electricity from biogas	23
Make provision of mixture device in inlet tank	47
Improve the quality of main gas valve/use good-quality valves	11
Establish service centers/formulate effective maintenance mechanisms	52
Design and construct plant in such a way that other feeding materials besides cattle dung could be used	41
Increase the size of plant/gasholder	23
Increase the diameter of the gas pipe	5
Commercialize the biogas plant with the introduction of community or institutional plant	52
Encourage users to construct two slurry pits compulsorily	88
Decide installation and size of plant based upon available feeding materials	41
Provide training and orientation to users on operation and maintenance of biogas plant	29
Activate media for promotional activities	17
Launch effective motivational/promotional activities to aware the people on importance and benefits of biogas plant	17

Some respondents gave more than one suggestions.

The responses as summarized above indicated that the users perceive subsidy as one of the motivating factors for the promotion and extension of biogas technology. They also strongly pointed out the need for effective maintenances after-sale services and Encourage users to construct two slurry pits compulsorily.

4.8 Hypothetical solution to increase the use of biogas

Present experience of the people with biogas is not good. But this study predicts that biogas has huge advantages than disadvantages. During conducting this study it gives some hopeful solution to face the problem that people experience during the use of biogas. By taking some important step this problems or challenges can take into an end.

- There is no proper propagation for biogas as a result public awareness is low. Hence proper propagation should be conduct.
- There is no mega project with biogas. So people do not understand how biogas can give huge opportunities of job, economic and environmental facilities. So mega project on biogas should be taken as early as possible.
- There is no proper source to take financial help to start a biogas plant. Financing is a big problem to start biogas plant as it required some extra money. Hence financing problem should be mitigating by funding more in the biogas sector.
- There is no publicity about portable biogas scheme. Proper publicity is required to increase the use of portable biogas scheme.
- There is no source of readymade biogas plant. If a biogas plant needed it is required to build it from beginning. The proper step should take to increase the use of portable biogas plant and its sources. Hence try to creating portable biogas plant business as other goods business.
- Some researchers are trying to increase the production efficiency of biogas. Some are trying to produce biogas from different feedstock. But it is confirm by many researcher and organization that it is quite impossible to increase the production efficiency of biogas at primary production level. The more waste supplied to the plant the more biogas will produce. On the other hand a comprehensive list of biogas yield data is available via the CROPGEN Database is available. The full database contains data for 729 different feedstocks and is available to download. So it is important to take the biogas in the field level than research on biogas production from different feedstock or increase the production efficiency. Biogas production from different feedstock or increase the production efficiency has already done by different researchers in different countries.
- Biogas is only used in raw form. There is no use of next generation level biogas technology. It is not purified or cleaned to use as other developed countries. So next generation level biogas technology should be introduce to increase the use of biogas.
- There is no clear data about biogas plant in Bangladesh like other developed countries such as United Kingdom, United States of America etc. So sometimes it is difficult to understand the real situation of biogas plant in root level. So there should be a proper and informative biogas map for Bangladesh like other developed countries such as United Kingdom, United States of America etc.
- Some important step has been taken by different organization of Bangladesh to spread the use of biogas. But among this organization's step the level of

synchronization is very poor. As their goal is same so they should work with more synchronization to get a proper result.

- A big amount of money is needed to start a biogas plant for industrial area. But there are no tax excuse facilities for them. Hence they are not interested to invest a big amount for biogas plant. On the other hand in house hold use of biogas is required some extra action like waste collecting and byproduct management regularly. By doing this they are benefited by a little financial help. But as the developed countries like Germany if we provide the tax excusing facilities for both use of biogas in house hold and industrial area it will encourage the people to use more biogas as energy.
- To increase the use of biogas in Bangladesh there is no declaration in any political party's handbill. So they should made proper declaration in their handbill to increase the use of biogas.
- Some people think that biogas is produce from dirty waste so it is also may be dirty. But it is not true. So people awareness should increase on technology of biogas production and use of biogas plant.
- Government and non-government organization should take proper step to increase the public awareness about biogas and help them from every angle to increase the use of biogas.

After all without proper and synchronize step it is not possible to face the challenges of biogas and also not possible to increase the use of biogas. So proper and synchronization step should take to increase of biogas.

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Chapter Five

Discussion and Conclusions

The principal purpose of this study is to outline or accumulation of knowledge about the experience on biogas of the dwellers at both town and village in Bangladesh as well as in other countries. And also to know why people do not use biogas as expected level though maximum facilities are available in Bangladesh. In addition, biogas is a century old technology. It is technically proven, economically viable and socially acceptable. Its technology is simple and locally available. All hazardous waste, that pollute environment, create disease, spread bad smell are the raw materials of a biogas plant. There is need and demand of gas, fertilizer and electricity without polluting environment. Biogas technology can ensure all. Due to anaerobic digestion, all harmful bacteria die. Through the process, the hazardous waste becomes clean gas and pathogen free rich organic fertilizer it gives a large amount of organic fertilizer drastically reducing carbon emission. It is very important for the agricultural economy of Bangladesh. Demand of gas and fertilizer is unending, raw materials are abandon and cheap.

After completing this study it is clear that people of developed and developing countries obtains positive experiences with biogas in large scale at different sectors. In those countries people not only use bio slurry as organic fertilizer, biogas for production of heat and steam, electricity generation but also purify and upgrade biogas to gas-grid injection and vehicle fuel. Most of the developed countries of the world such as Austria, Germany, United Kingdom, Sweden, France, United States of America etc. have a target to increase the use of biogas 20-50% of total energy before 2020. On the other hand, most of the developing countries of the world such as China, India, Nigeria, Ethiopia etc. have a target to increase the use of biogas 15-30% of total energy before 2020.

On the other hand, it is clear that people of Bangladesh obtains huge positive experiences with biogas in social, economic, environment, health and daily life sector.

- In daily life sector about 88% people has experienced that biogas plant is safe to use and about 23% people has experienced healthy environment for cooking in the kitchen. The positive experience of daily life sector is shown in table 26.
- In health sector near 76% people has experienced free from the cooking in suffocating environment and 29% people has experienced that in anaerobic digestion system biogas plant destroy harmful bacteria and parasites and keep environment healthy. The positive experience of health sector is shown in table 27.
- In economic sector about 82% people has experienced that they can save money because biogas replaces the expensive firewood, charcoal and kerosene etc. and near 5% people has experienced that no need to pay extra money to heat room in required condition. The positive experience of economic sector is shown in table 28.

- In social sector near 76% people has experienced that they can visits one another house due less workload and about 23% people has experienced that it is required less wood hence no need to cut down tree. The positive experience of social sector is shown in table 29.

After all, at present the experience of the people of Bangladesh about biogas is at a satisfactory level though there are lots of rooms for further improvement. Both the people of developed and developing countries have better experience than people of Bangladesh.

- Near 82% people has experienced social limitation and psychological prejudice against the use of raw materials
- About 5% people has experienced that sometime hard to collect required waste for plant.

The negative experience of different sector is shown in table 31.

These negative experiences are not considered as alarming problem and its nothing but the consequences of ignorance. Because maximum of these can be overcome or reduced by following some precautions

- About 82% people are suggested to reduce the cost of installation.
- About 5% people are suggested to increase the diameter of the gas pipe.

The suggestions of the users are given in table 32.

These problems can be resolved easily by taking it as a challenge. Taking proper and synchronized steps such as conducting propagation, start mega project, by increasing the fund in this sector, tax excusing facilities, increase portable biogas plant uses, use higher level biogas technology, include declaration in political party's handbill, increase public awareness, taking step by government and non-government organization etc. can be helpful to overcome these challenges.

This study accumulates both the positive and negative experiences of the people of Bangladesh and other countries. On the other hand, it also finds out some hypothetical solution to increase the use of biogas as expected level in Bangladesh. If it is possible to overcome the challenges, there will be a great hope for gigantic potential source of biogas in Bangladesh. And also it will be helpful to fulfill the target of Bangladesh to increase the use of renewable energy 10% of total energy before 2020.